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Spaceflight

The International Magazine of Space and Astronautics

Space Go-Ahead for Europe

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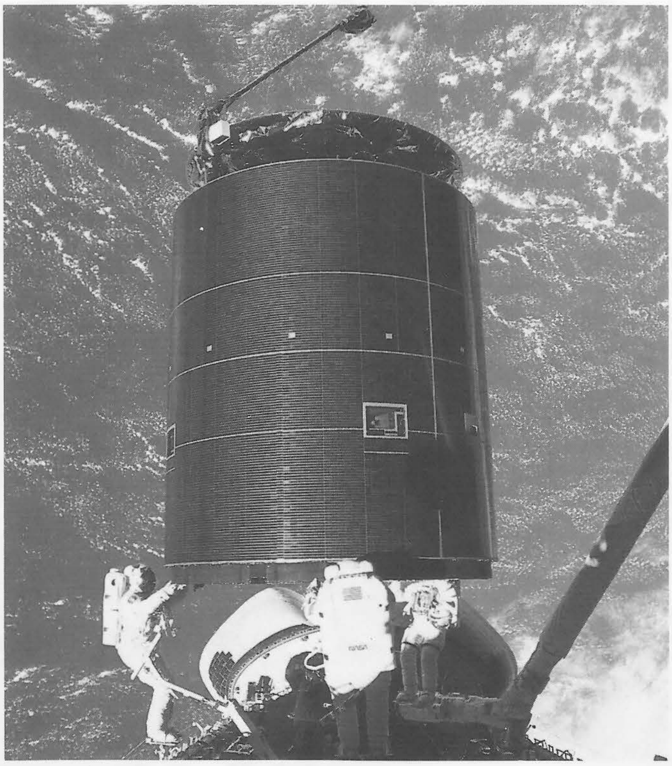

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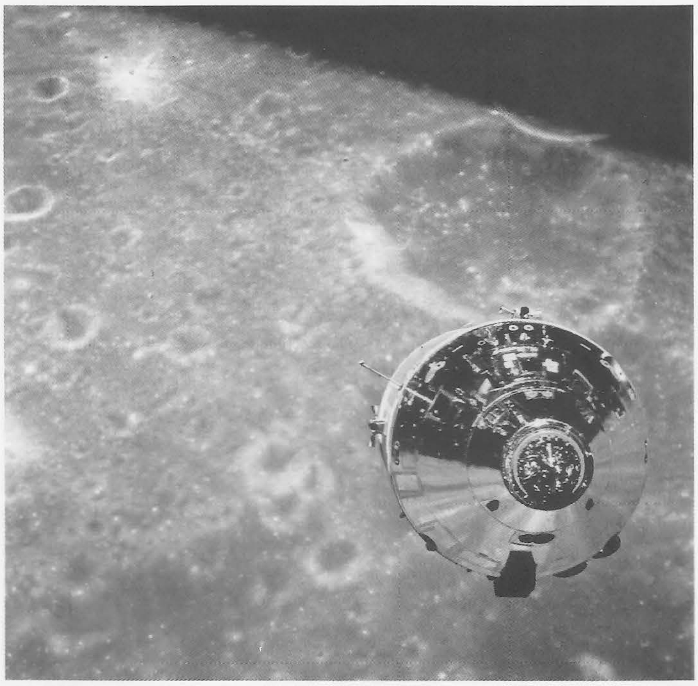

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***Front Cover:** A Manned Mars Probe Approaching the Planet.* *P.G. Goodwin BA, FBIS*

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ESA Chief Meets MPs

- *ESA's Director General at House of Commons Highlights UK Commitment to Earth Observations*
- *Manned Space Flight Plans Look to Cooperation with the US, Russia and Japan*

Following the 13 nation Council of Ministers Meeting in Granada In November, Jean-Marie Luton, Director General of ESA, visited the UK Parliamentary Space Committee, under the Chairmanship of Sir Michael Marshall, MP on December 1, 1992. Attending on behalf of the BIS was Council member ***Dr Paul Thompson*** **who writes this report for** ***Spaceflight.***

In frank and open discussion, Jean-Marie Luton spoke about his feelings on ESA's future programme following the Granada Meeting. "During this visit to the UK", he said, "I am pleased to be able to address the Parliamentary Space Committee and other interested parties as it helps me to understand the mood of the UK towards ESA. I am pleased that the Ministers at Granada expressed their faith in space and ESA by endorsing a significant multi-phase programme with a considerable budget during a period of complex and difficult times, with recession hitting many member states".

Earth Observation

The Director General highlighted the commitment made by the UK to Earth Observations and the many facets that the ESA programme had in this area. Without this strong push from the UK he would have found it difficult to achieve the outcome of Granada. He also indicated that, in the light of current concerns about the environment, the UK campaign for the adoption of advanced concepts and technology in the Earth Observations field was a major thrust in achieving agreement and in cooperating with EUMETSAT on a most worthy programme.

Manned Space Flight

He expressed some disappointment that the manned space flight plans of ESA had been the subject of significant revision but was heartened by the prospects of increased international cooperation in this area with the US, Russia and Japan. This he said was 'a sign of the times' and all attempts to go it alone with manned flight had suffered, making a cooperative approach the most sound.

Advanced Launchers

On advanced launch capability outside of the Ariane programme the Director General indicated that he was enthusiastic about the FESTIP programme and that he recognised the foundations laid down in this area by activities in the HOTOL and SANGER projects. This now required building upon as there was much to be gained from the advanced propulsion work, however, he cautioned that this needs to be handled in a planned and controlled manner as not all member states were as supportive as the UK in this area.

Company Mergers

Questioned about the increase in mergers between space oriented companies he indicated that this was inevitable at this time due to the economic pressures. In some ways such mergers posed a challenge for ESA because of its geographical return arrangements but this is offset by the capabilities that such merged companies have in their portfolios.

Financial Aspects

On the question of the viability of contributing in kind rather than on a monetary basis to the US programme he indicated that although much remained to be resolved at the detailed level there was an understanding and agreement between him and Daniel Goldin of NASA on the concept and the way forward.

The issue of addressing how to handle fluctuating exchange rates was an important one, but was not too difficult for ESA as much of the funds contributed by a member state are spent in that country. ESA is studying the matter and will make recommendations soon on how to progress.

The UK and ESA - A Plan

At their previous Council meeting in Munich in November 1991, ESA's Council of Ministers failed to agree the long-term plan submitted by ESA's Director General and asked him to trim his budget. The proposals submitted to the Granada Ministerial Council in November 1992, involved some £2.5 billion savings over Munich with a new budget for 1993 - 2000 of around £18 billion.

Britain achieved its objective for the Granada Meeting which was to secure the go-ahead for ESA's future Earth observations programme, previously known as POEM 1 (Polar Orbiting Earth Observation Mission 1). This comprises two elements:

ENVISAT 1 - an environmental mission carrying an advanced British radar for launch in 1998

METOP 1 - a polar meteorological/climatology mission procured jointly with Eumetsat for launch in 2000.

Both of these missions will fly on a British designed Polar Platform which was also given the go-ahead at Granada. The UK is contributing some £400 million to these programmes.

The Council also decided to proceed with the first Data Relay Satellite which is planned for launch in 1999.

Most of the impact of the reductions in the cost of the Long Term Plan fell on ESA's ambitious and costly manned space programmes. Of these, the only one to survive intact (though with an imposed reduction in cost of 5% and subject to confirmation at the next Ministerial Council in 1995) was the Columbus Attached Pressurised Module (APM) laboratory which will dock with the US Freedom space station. The APM will now be developed for a 1999 launch, one year later than previously planned. The Columbus Man Tended Free Flyer, ESA's autonomous space laboratory was abandoned, while the Hermes mini-shuttle is to be reorientated over two years of studies for possible roles in crew transportation in possible collaboration with the US or Russian Federation.

The UK has around a 23% share in POEM 1 and Polar Platform, a 1% share in Data Relay Satellite and up to 1% in the APM, but does not participate in Hermes (or, of course, Ariane 5).

The Granada Council also recognised

What the Granada Meeting Means for ESA

ESA has 'a two year breathing space' according to *Norman Longdon,* Fellow of the Society, who now looks at the prospects for European space programmes up to the end of the present decade.

Against a background of recession and recent financial market upheavals, the Ministers responsible for space in the member states of the European Space Agency met in Granada. The outcome was much more positive than might have been expected, and ESA has a two year breathing space, and a defined programme. Certain codicils have been added, but ESA has until 1995 to sort out a longer term path.

At the head of the list is, not unnaturally, Earth observation. The success of the European remote sensing satellite, ERS-1, and the 'green' tint still of all European governments ensured that there would be full backing for the next steps in the development of remote sensing from space. ESA is already at work on the follow-up satellite ERS-2, and the Ministers approved the Envisat-1 mission, planned for launch in 1998. The mission will be mainly dedicated to understanding and monitoring the environment, and will provide radar data as a continuation of the data due to be provided by ERS-2.

Meteorological observations are currently taken care of in Europe by the Meteosat series, but new methods are needed. Eumetsat, the sister organisation responsible for the operational meteorological satellite systems across Europe, will join ESA in preparing the development of a new mission Metop-1, subject to Eumetsat approving the necessary finances. Like Envisat, this mission will use the Columbus polar platform. As such it is a departure from the geostationary meteorological satellites so far developed. The planned launch is in 2000; more on the use of polar orbiting weather satellites in a later article. The Ministers also welcomed a proposed collaboration between the two organisations to develop a second generation of Meteosat satellites.

One subject now tackled is that of the use of Earth observation data. The sheer quantity, and the excellent quality of the ERS-1 data, are beyond expectations, and international organisations such as the European Communities, as well as national agencies, are potentially big users of the data. Quite rightly ESA is expected to take the initiative in bringing them together so that a solid basis can be formulated for the future European Earth observation policy.

Data of all kinds is the main out-turn from space research, and means of ensuring that it is received where and when it is most needed are critical. The Ministers understood that a data relay system was therefore very important in any future policy. Approval was given for the full development of the first DRS satellite for launch in 1999. It will be a 'work horse' for many programmes, especially the Earth observation satellites.

Man-in space continues to be a hard talking point in space circles around the world. The pros and cons are well known, and so far no real line has emerged. The European contribution from Granada is a decision to go ahead with the Columbus Attached Laboratory as part of the International Space Station Freedom. Some scaling down to meet the financial resources will be necessary, and the longer term question of the utilisation of the space station is still under discussion. Hermes, and other forms of space transportation will be studied further, to enable a decision to be made in 1995. System studies on an ESA-Russian crew transportation vehicles, and development of critical technologies based on the Hermes definition will be undertaken during the period 1993-1995. Cooperation with the USA will include a detailed study of an ESA Assured Crew Return Vehicle (ACRV).

The codicils include the need for ESA to negotiate with NASA the terms of an agreement on the allocation of the exploitation costs of the international space station. These negotiations centre round the member states' request that NASA makes a commitment that ESA's contribution to the space station annual common system operations costs will remain under a firm fixed financial ceiling, and also that a significant proportion of that contribution should be made by the provision of goods and services in kind, such as the ACRV, the automated transfer vehicle (ATV) using the Ariane launcher, and the data relay system.

The Agency has not escaped the results of the financial market and ERM turbulence. Several countries are seeking ways to reduce the effect that the devaluation and realignment of currencies has had on their contributions to the Agency's programmes. But when an answer is found to these problems, ESA has positive signs from its governments that a strong push towards the next century is well within the political will and practical possibilities for European Space.

for the Years 1993 - 2000

the future need for a second-generation Meteosat system and a longer term European space transportation/launcher programme (FESTIP). Ministers also adopted a UK resolution endorsing the work of the international Committee on Earth Observation Satellites (CEOS) in laying the foundations of a global space agency.

The net effect of these various changes is to place Earth observation at the top of the ESA agenda.

The UK also secured agreement for ESA to re-examine the formula it uses to take account of exchange rate fluctuations. Over two-thirds of UK's £100 million annual contribution to ESA is paid directly to British agencies in £ sterling, but according to ESA's present formula the recent devaluation would require supplementary payments of £5 million in 1994 and £20 million in 1995 over and above the direct annual cost of £20 million.

The main programme budgets approved at Granada were:

Programme	Budget (£M)	% UK Share
POEM 1:		
ENVISAT	800	21 - 25
METOP 1 prep.	30	14.6
Data Relay Satellite	665	1
Columbus Polar Platform	490	22.6
Columbus Attached Module	1800	1
Hermes Reorientation	400	Nil

BNSC 1992/3 payments are as follows:

Programme	ESA* (£M)	National (£M)	Total (£M)
Earth Observation	42	42	84
Science	32	14	46
Communications	19	1	20
Technology Support	-	4	4
ESA General Budget	12	-	12
Launchers	1	-	1
Totals	106	61	167

* Payments to ESA amount to 7% of ESA's total budget.

SPACE POLICY

A New Pattern for International

Part 1 - Acquiring Space Capability

There are very few major space projects that do not, in some way, involve nations working together. Space engineering is perceived as expensive and by sharing projects the cost to each nation should be lower than doing them alone. This would seem to be particularly true of infrastructure projects. Infrastructure systems are those that provide the basic capability to undertake space activity. They include launch vehicles, space stations, transfer vehicles, data relay satellites and Lunar bases. They tend to be the biggest and most expensive space projects undertaken and thus the most attractive to conduct on an international basis. Yet the final results on such international infrastructure programmes has been very disappointing.

BY MARK HEMPSELL
University of Bristol

Spacelab (the European contribution to the US Space Shuttle) left America with very little, if any, cost saving and it left Europe with a heavy investment in a system it cannot afford to use properly. The Columbus Attached Pressurised Laboratory, the European contribution to the US Freedom space station, now looks like being a very similar story. Freedom's costs have risen while the crew size has shrunk, so Europe will not have the access to space it originally expected when it signed on. Yet the US has not saved any money on the development of Freedom; indeed the international nature of the project may actually have made it more expensive for them.

In the case of Hermes, France, unlike America, is prepared to give away critical elements of the system to its partners and so does achieve a real cost saving over doing it alone. However, the end result has been a system that has totally failed to provide the space capability that the partners, like Germany, needed. As a result, the project's future is now in serious doubt.

The Old Pattern

So what went wrong? The real answer is a great many things, most of which have nothing to do with international collaboration.

An examination of the way past programmes were organised shows that in every case there was a lead nation that decided what the project objectives should be and how they should be achieved. It reached these decisions without any effective consultation with its potential partners, who could then only participate as junior partners with the lead partner controlling:

- ❑ The nature of the contributions of the junior partner.
- ❑ The standards, interfaces and other technical managerial interactions.
- ❑ The support infrastructure.
- ❑ The junior partner's utilisation of the system, when operational.

In practice, a junior partner would have limited control over its investment costs and no control at all over the operational cost or its access to the capability it has invested in.

The last point highlights the second feature of current international programmes. Only one system is ever built. For example there is only one Space Shuttle system - under the control of NASA, one Ariane launch system - under the control of Arianespace, and there will be only one Space Station Freedom - again under the control of NASA. So universal is this pattern that most people in the space business see it as natural, yet it is the equivalent of Boeing or Airbus, as a matter of policy, selling aircraft only to one airline.

Given this catalogue of failure, where in most cases the lead partner does not save money and the junior partner ends up with no practical control over his own investment, the obvious question that arises is "Why does everybody continue doing it this way?"

The key to answering this question lies in the way we have been judging these programmes. The above discussion is based on the premise that they are infrastructure programmes and therefore judged on how effective they are at providing capability. Indeed, ultimately this is the normal and obvious criterion used to evaluate success. However, during the early development stage and the time when agreements are entered into, the story is very different.

The infrastructure function of the system is indeed one of the rationales during the selling phase of a programme but other rationales are also normally included such as:

- ❑ Advancing technology.
- ❑ Enhancing national prestige, maintaining leadership.
- ❑ Reinforcing general international ties.
- ❑ Contributing support for the aerospace industry.

By the time a typical infrastructure project actually starts it has become all

*Based on a lecture to the British Interplanetary Society in London on June 3, 1992.

SPACE EDUCATION

Teaching the Teachers

ALEX ELLERY*
UKSEDS, Chairman

There is little doubt that space is the ideal catalyst to sparking school pupils' interest in science and technology in general. Indeed, the education fraternity is not lost to this: the National Curriculum now specifies "The Earth in space" as one of the science module attainment targets. Space is in vogue in the education world. A host of undergraduate and postgraduate courses in astronomy, space science and technology are flourishing that did not exist a few years ago. What is more, these courses are attracting the best students that schools and universities have to offer. This is all well and good, but a major stumbling block remains - the majority of school teachers of physics have had little or no background or training in space-related disciplines.

It has been pointed out [1], that most teachers of physics are not confident teaching astronomy. The situation is worse when we consider space science and technology. The Technology and Design curriculum has superseded the old technical drawing, arts and crafts subjects. Consequently, Technology and Design tends to be taught by teachers trained in those subjects rather than engineers. Yet space could be introduced into the Technology and Design curriculum with little difficulty. Other possibilities include environmental issues: the advent of remote sensing of the environment is now a hot topic in schools, but teachers are generally ill-equipped to take advantage of what is available.

In response to this need, UKSEDS (UK Students for the Exploration & Development of Space) in conjunction with Cranfield Institute of Technology (CIT) held a 3-day residential Space Education course for secondary school teachers at the Cranfield College of Aeronautics in Bedfordshire from 11-13 August 1992. The course was run on a non-profit making basis and was designed to provide the delegate-teachers with the training to teach all aspects of astronomy, space science and technology at GCSE and A level. Heavily geared towards science and technology, CIT has a strong space technology and space physics group from whom several of the course lecturing staff were drawn. Their considerable experience in hosting short courses for industry made them the ideal site for the Space Education course. The course was structured around a series of two-hour lectures during the day and more informal sessions during the evening.

Michael Rycroft introduced the 11 delegates to the nature of the "Space Environment", stressing the effects of the Van Allen radiation belts. Barrie Moss

Space Collaboration*

things to all men and is often accompanied by a unrealistically low projection. With such a wide range of objectives, compromises have to be made during the development and it is *how* those compromises are made that determines the true objective of the programme.

On this evidence it is clear that it is national prestige and technology development that are the real reasons why such projects are proposed and supported. Hermes is a particularly clear example. Its infrastructure role is to transport men into space, a job that could more easily, cheaply, quickly and safely be accomplished by a simple capsule. Yet the system was turned into a winged aerospaceplane to get a perceived technology edge. The problems due to this schizophrenic infrastructure/technology approach grew until something had to be abandoned. The latest version of Hermes is an unmanned technology advancement programme, with all pretence at infrastructure expansion abandoned. Shuttle, Freedom, Spacelab and Columbus, while less spectacular, all have examples of a technology/prestige requirement overriding an infrastructure requirement.

We can conclude that, in the western world, the so-called infrastructure programmes are actually conducted to improve technology and national prestige. Judged against these objectives most of the programmes have not come off too badly. The lack of actual space capability is embarrassing, maybe even undesirable, but it does not actually make the programme a failure. From this viewpoint it is not surprising that acceptance of the current collaboration pattern is so widespread.

To reinforce this point it is interesting to compare these large space programmes with other international science and technology projects. Examples of such projects would be CERN, or JET, or the large astronomical telescope. All these also feature only one facility and normally have a lead (and dominating) partner. So the pattern used by space programmes merely follows the traditional pattern used in non-space international science and technology projects.

A New Pattern

What then would be a suitable collaboration pattern? We can begin to answer this question by examining what governments do when they are interested in real capability.

The classic examples for our purposes are the European military aircraft projects such as Tornado, as these clearly are not developed using a science and technology pattern of collaboration. In this case the partners are really interested in what the system can actually do. They cooperate and share the acquisition phase (development and manufacture) on a much more equitable basis than with science and technology programmes. The partners then build as many of the eventual product as is required to satisfy the needs of each partner. These are then under the total control of the individual partner, to exercise its own policy without interference by the other partners.

The key features of this capability orientated pattern contrast strongly with the current science and technology pattern. Rather than one lead nation dominating junior partners there is a more equitable arrangement whereby all partners get a say in the overall specification and objectives, and all partners get a key element of the project as their contribution. This should, in itself, ensure that the per nation cost is significantly lower than going alone.

The second major difference is that several identical systems are built rather than a single system. At least one for each

Mr Mark Hempsell
BIS Council Member

partner, but more if more capability is required. This means that the balance of where acquisition costs are incurred moves from development to production. which ensures that the overall cost is significantly lower than if all the partners developed and constructed one system each. This shift in the balance between development and production has the additional benefit of spreading the acquisition budget more evenly and so the peak annual funding requirement is lowered.

Another difference is the degree of control which each partner has. The autonomy in operations is obvious but a partner also gets more control over the investment. Development and production of the element would be to standards agreed by the partner rather than imposed by a lead nation. Further, by making each partner responsible for the delivery of his element, costs incurred in the support infrastructure are also under the partner's control.

The only potential problem in starting up such a pattern is when the prospective partners have widely differing requirements. However, the nature of the space infrastructure is that the basic capability required, e.g. to launch payloads, or to support men in space, is the same whatever the nation. Differences in space objectives that currently separate nations only arise when science, technology and prestige issues are introduced. Providing the objectives remain the acquisition of space capability, the establishing of common requirements should not be difficult.

In a following issue of ***Spaceflight****, Mark Hempsell concludes this article with 'Part 2 - Space Station and Lunar Base Development'.*

then delivered his lecture on "Rocket Propulsion" emphasising the colossal overheads involved in launching payloads. After lunch, Alan Wells used the examples of ERS-1 and ROSAT to discuss "Space Instrumentation". The final lecture of the day was on "Orbital Mechanics" by Jehangir Pocha who started with Kepler's Laws progressing to orbital transfers and ground tracks from satellites. The day was still not done however: after dinner, the delegates were subjected to a UKSEDS presentation of their on-going project work and the film *For All Mankind*.

The following day, an early start was made with Max Noton on "Guidance Navigation & Control" using the Comet Sample Return mission as an illustration. John Stollery then introduced delegates to re-usable "Spaceplanes", in particular HOTOL. During the afternoon, the lectures switched to astronomy. Carl Murray spoke about "Planetary Astronomy" in the context of recent probe missions. David Stickland discussed "Stellar Astronomy" from the perspective of spaceborne instruments. Peter Coles delivered the final lecture of the day on "Galaxies & Cosmology" in the context of the COBE results. The evening was more relaxed with a model rocket display by Howard Foare demonstrating his Saturn V and Saturn IB models in action. The last leg of the day was an extremely fruitful discussion forum chaired by UKSEDS committee members concerning the requirements of space education.

The final day began with Mark Leese on "Spacecraft Systems" who concentrated on spacecraft structure, thermal control, on-board power generation and telemetry and tracking. Craig Underwood talked about "UoSat and Education" followed by Ron Broadbent on "Amateur Radio Satellites" to provide a flavour of working on a specific system geared towards education. The course was finally wound up by Geoffrey Pardoe who related the history of "Britain in Space" and Chris Elliott who discussed the human side of "Space Agencies and their programmes".

The course was a huge success and we hope that it provided some small measure of assistance to the education process. I quote from letters written by some of the teacher-delegates: "...I couldn't believe on Thursday evening that the course was over. I'd adjusted to thinking of 12 hours listening per day as normal and am now suffering withdrawal symptoms...", "...the course was unforgettable..."

Reference

1. J. Baxter, "The National Curriculum: a challenge for astronomers", Quarterly Journal of the Royal Astronomical Society, 32, pp.147-57 (1991).

*Alex Ellery is a PhD research student at Cranfield Institute of Technology.

Extra-Terrestrials Search Stepped Up

Is there anybody out there? Or is planet Earth a lone oasis of life in a vast, uninhabited universe? The answers to these fundamental questions which have intrigued humanity for thousands of years may soon be known. The American space agency NASA has recently initiated the most intensive search for extraterrestrial intelligence (SETI) ever attempted.

BY PETER BOND

The debate over the presence of intelligent life elsewhere in the universe tends to provide two different viewpoints. Humans have become accustomed to the idea that they are the chosen species, the pinnacle of the evolutionary tree. Yet, ever since ancient times, philosophers such as Lucretius have argued that there are "other worlds in other parts of the universe, with races of different men and different animals".

Early this century, when H.G. Wells wrote *War of The Worlds* and the American astronomer Percival Lowell described canals on Mars which had been built by an advanced civilisation, many people believed implicitly in the evolution of life on other planets.

Today, the advent of the Space Age has bred familiarity with space travel and the nature of the cosmos, with the result that alien life forms are once more an accepted ingredient of popular culture. Films and TV series such as *Star Trek, Star Wars, ET* and *Close Encounters of the Third Kind* are based on the supposition that intelligent species with widely differing shapes and characteristics exist throughout the Galaxy.

With an estimated 400 billion stars in our Galaxy alone, many of which are comparable in size and age to the Sun, the chance of other planetary systems existing is very high and proof may be forthcoming in the near future as modern detection techniques reach the level of sophistication required.

The Sun is thought to be only half way through its 10 billion year life cycle, so it is by no means beyond the bounds of possibility that life may have evolved on planets which formed before our Solar System was created. Assuming a similar rate of evolutionary development on such favoured worlds, it is quite likely that cultures and civilisations thousands or even millions of years in advance of ours may exist.

If there are so many planets which support intelligent life, why, it might be asked, have they not contacted us, and how could we contact them? The answer seems to lie in the scale of the universe. The stars are so far apart that it is almost impossible to bridge the interstellar gulf. Even the nearest star is more than four light years away.

Travel at near-light speed (186,000 miles per second) is far beyond our current capability and much slower speeds would stretch the journey beyond a crew's life span. The Voyager spacecraft which left Earth in 1977 will not reach other star systems for tens of thousands of years.

This means settling for some remote form of communication such as electromagnetic radiation and one region of the spectrum stands out as the prime candidate - radio waves. Only in the microwave 'window' between 1,000 and 60,000 MHz is the Galaxy fairly quiet.

A transmitter operating at such frequencies requires only modest power to produce a detectable cosmic signal. Radio waves are also ideal since they travel at the speed of light and are not absorbed by dust or gas on their journey between the stars.

Until the 1950's astronomers did not have the technology available to fully utilise the potential of radio waves and it was in 1959 that the first eloquent plea for recognition of the importance of SETI was made. Writing in the journal *Nature*, physicists Philip Morrison and Giuseppe Cocconi of Cornell University wrote:

> Few will deny the profound importance, practical and philosophical, which the detection of interstellar communications would have. We therefore feel that a discriminating search for signals deserves a considerable effort. The probability of success is difficult to estimate; but if we never search, the chance of success is zero.

One of the pioneers in the field of SETI was Frank Drake, now Professor of Astronomy at the University of California in Santa Cruz. When he began the modern era of SETI in 1960, it was still seen as the domain of the lunatic fringe, a pseudo-science to be avoided at all costs by the serious scientific community. Only Drake's persistence enabled him to scrape 200 hours on the radio telescope at Green Bank in West Virginia for a preliminary study of two nearby Sun-like stars known as Tau Ceti and Epsilon Eridani.

If there are so many planets which support intelligent life, why, it might be asked, have they not contacted us, and how could we contact them?

Project Ozma failed to find any artificial signals, but, vigorously supported by eminent scientists such as Drake, Carl Sagan, Paul Horowitz and Bernard Oliver, SETI gradually gained a mantle of respectability.

These early pioneers realised that their only hope of detecting unnatural signals was to screen out the random radio noise which filled the sky. Earth is surrounded by a 'bubble' of ultrahigh frequency signals which is expanding outwards at the speed of light (186,000 miles per second). This radio, radar and television 'leakage' from our planet currently fills an area of space nearly 100 light years in radius.

Such unmistakable evidence of intelligent life on Earth could have been detected by an advanced civilisation anywhere inside this sphere, with the result that a reply could be winging its way across the void at this very moment.

On the other hand, it also acts as a barrier to any SETI search. The rapidly increasing radio pollution which surrounds our planet is threatening to close the microwave window before we have a proper chance to peer through it and examine everything in our field of view.

Bernard (Barney) Oliver, Deputy Chief of the NASA SETI programme, bewails this deteriorating state of affairs: "Many portions of the window are already lost to us. The growing radio interference problem is decreasing the completeness and extending the time required for the search". It is already impossible to detect certain ETI signals because they would be swamped by human interference.

When trying to detect an alien civilisation, the obvious thing to look for is a signal which demonstrates intelligence. Stars and galaxies give off a maze of random, irregular radio waves, but signals generated by humans are either continuous or pulsed, and concentrated in narrow wave bands.

Rather than attempt a blanket search of the sky across some 10 billion channels in the microwave window, many investigators have tried to find the needle in a cosmic haystack by taking a short cut. They believe that the best frequency band for interstellar communication lies between 1420 MHz (the hydrogen spectral line) and 1662 MHz (the hydroxyl or OH spectral line).

Since these are the constituents of water, a vital resource for life as we know it, this region of the spectrum might be favoured for transmissions by other civilisations. The "cosmic water hole" has been examined by

numerous SETI teams, but so far to no avail.

Search techniques have not always been restricted to simple listening. In 1974, for example, Drake devised a simple message in binary code which he then transmitted towards a large star cluster 24,000 light years away.

Despite increasing scientific interest and repeated recommendations from the American National Academy of Sciences, official funding of SETI has so far been limited. Every year, Congress has second thoughts about committing $100 million of tax payers money to the new search for extraterrestrials. As one Congressman commented, "We don't need to spend six million this year to find evidence of these rascally creatures. We only need 75 cents to buy a tabloid at the local supermarket".

Such scepticism has meant that funding for the most comprehensive SETI programme of recent years has been left to the Planetary Society, using donations from the general public, including $100,000 from film producer Steven Spielberg. The META (Megachannel ExtraTerrestrial Assay) survey, as it is called, has been operating in the United States since 1985, and scans more than 8 million channels. In the last two years it has also been extended to Argentina to enable a complementary survey of the southern sky. So far it has checked about 1/10,000th of the possible SETI frequencies. Yet this will pale into insignificance now that the latest NASA project has come on stream.

On 12 october 1992, the largest radio telescope in the world at Arecibo in Puerto Rico and a newly commissioned 34 metre dish antenna at Goldstone simultaneously began NASA's High Resolution microwave Survey (HRMS). If funding allows, this latest programme will employ radio telescopes all over the planet until at least the year 2001.

Barney Oliver argues that this is the best time to start such a search. "While the cost of the equipment has been dropping and will continue to drop, the cost of doing the search itself will increase". He goes on to argue that, if the programme is delayed for another decade, the precious microwave window will have disappeared.

Scientists intend to use two complementary search strategies:

The Targeted Search, led by NASA's Ames Research Center, is based on the assumption that inhabited planets should exist in similar environments to our own. Large, highly sensitive radio telescopes such as Arecibo will concentrate on 800 Sun-like stars which are in our part of the Galaxy. The automated search will take a close look in the frequency range 1,000 to 3,000 MHz, trying to pick out the tell-tale narrowband signals.

The Sky Survey, managed by NASA's Jet Propulsion Laboratory, will examine the remaining 99% of the sky by using smaller, less sensitive antennas like the Goldstone dish which can probe a wider range of frequencies. Although the amount of time spent on investigating any part of the sky will be small, scientists are hoping to pick up strong signals from distant sources.

This radio, radar and television 'leakage' from our planet currently fills an area of space nearly 100 light years in radius.

One major innovation is the creation of a large mobile trailer, loaded with detection systems, which can be flown around the world to different participating observatories. The new hardware and software developed for this programme will significantly increase the chances of detecting signals from other civilisations.

Using receivers which can tune in to more than 10 million channels simultaneously, the computer system will scan the radio power in each channel about once every second. As Drake proudly admits, "The system can do in a fraction of a second what it took me 200 hours to do just 30 years ago". Indeed, more searching was done in the first few minutes of the HRMS than had been done by all of the previous 50 SETI programmes.

The tremendous capabilities of this new system have been made possible by the rapid advances in digital signal processing technology, and by substantial periods of observing time provided by some of the world's largest or newest radio telescopes.

Further developments are in the pipeline. The Planetary Society is raising funds to introduce its BETA system by the end of 1993. According to its Executive Director Louis Friedman, the new system will complement NASA's effort, and in some ways improve upon it, by using the world's largest spectrum analyser to scan the entire sky at high resolution. The Society's eventual aim is to extend the search even further by introducing a system capable of searching six billion channels, including complete coverage of the "water hole".

Detailed post-detection guidelines for individual scientists and organisations have already been drawn up by the SETI committee of the International Academy of Astronautics

Launch of a Russian satellite called Radioastron in 1995 should also provide improved sensitivity. Searches of unprecedented resolution will be made possible by linking the 33 feet diameter antenna of the orbital radio telescope to large ground-based instruments around the world.

Meanwhile, despite numerous false alarms, there have so far been no signs that we are anything but alone. So what if nothing is detected in the next 10 years? Does it mean we are really alone? Barney Oliver comments: "Failure to detect a signal would not mean that extraterrestrial intelligence does not exist, it would merely prove that we need greater antenna collecting area to detect less powerful signals - the kind we ourselves radiate".

Frank Drake answers this query in a different way. He recalls the infamous episode of 1924 when Mars passed close to our planet and the world waited to receive a message from its inhabitants. Mars remained silent.

"The people of those times were eminent scientists, and they thought they understood the universe. They were very confident in their beliefs. To us they were foolish, and this is a warning to us today, that, when we, too, feel very confident of our approaches to SETI, maybe we're not quite as smart as we often think we are".

Equally momentous would be the discovery that someone else really was out there, perhaps even sending us a message of some kind. As the *New York Times* once commented, "It would be the biggest science story of all time". The most important, and perhaps most difficult, follow up would be to obtain absolute confirmation of the discovery before it was announced to the world.

Detailed post-detection guidelines for individual scientists and organisations have already been drawn up by the SETI committee of the International Academy of Astronautics and endorsed by other international scientific bodies. Their aim is to avoid at all costs the possible spread of mistaken ideas, wild rumours, confusion and even hysteria among the public. A second declaration of principles regarding the best way to send a reply from Earth is currently being prepared.

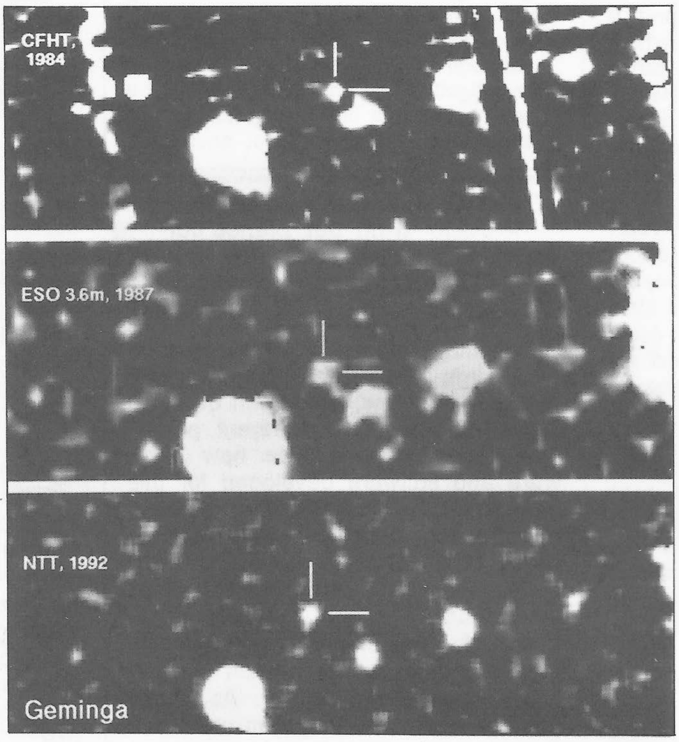
So how should we feel about he possibility that there are other intelligent life forms in the Galaxy, some of them possibly far more technologically advanced than ourselves?

One person who is enthralled by the idea is Frank Drake. "I find nothing more tantalising than the thought that radio messages from alien civilisations in space are passing through our offices and homes right now", he enthuses. Whether you agree or not, there is little doubt that, one way or another, the next decade of SETI will have a most profound impact on our perceptions of life, evolution and human destiny.

Spinning Geminga

Recent observations have identified the optical emission from mysterious Geminga. Although the second strongest source of energetic gamma-rays in the sky, Geminga's optical image is extremely faint and its real nature has long been a subject of debate. A break-through became possible when the object's motion in the sky was discovered and accurately measured.

As a consequence, Geminga is now believed to be the closest neutron star known to us, at a distance of no more than 300 light-years, possibly even less.



The Motion of Geminga

The motion of Geminga, now believed to be the nearest known neutron star. The fact that it is moving was discovered in early November 1992 on the basis of these photos. The rate of motion indicates a distance of about 300 light-years (100 parsec).

The star-like image of Geminga's optical counterpart, known as G" and with a magnitude of 25.5, is indicated in all three photos which show the same sky field, as recorded by CCD cameras at different telescopes in different years. The upper photo was obtained on January 7, 1984 and it is a composite of 12 individual exposures of 15 min each under good seeing conditions (0.9 arcsecond). At that time the CCDs were considerably more noisy than now. The middle photo was obtained on January 29, 1987. It consists of 8 superposed exposures of 15 min each. The lower photo was made November 5, 1992. Ten exposures of 15 min each were combined.

The measured motion of G" between 1984 and 1992 is 1.5 arcsecond, corresponding to about 0.2 arcsecond/year. The direciton of the motion is towards North-East (upper left corner).

European Southern Observatory

Elusive Geminga

Geminga (see ***Spaceflight***, July 1992, p.223) was first detected as a strong gamma-ray source in 1972, by means of instruments onboard the SAS-2 and COS-B satellites. Its name comes from "the GAmma-ray source in the constellation GEMINi" and also means "It is not there" in Milanese dialect. Gamma-ray instruments recorded this energetic radiation from a relatively large sky area so Geminga's position could not be accurately determined. This made it also impossible to identify an optical image lying anywhere in a wide Milky Way field. Thousands of Milky Way stars appeared within the "error-circle", i.e. the sky area corresponding to the uncertainty of the position of the gamma-ray source.

In 1983, Giovanni Bignami and his collaborators in Milan identified Geminga with a weak X-ray source observed with the Einstein X-ray satellite. Since the X-ray position was more accurate than the gamma-ray position, it became possible to narrow down the search area to a smaller sky field only about 10 arcseconds across. Long exposures made with very sensitive optical CCD cameras of this sky area showed several very faint stellar images. One had a bluer colour than any other stars in the field. Its brightness corresponded to magnitude 25.5, i.e. almost 100 million times fainter than that perceived with the unaided eye. This "star" was given the provisional designation G" (two other stars in the field were called G and G').

Pulsations from Geminga

It then became clear, immediately, that Geminga must be a very strange object, since it emits almost all of its energy in the form of very energetic gamma-rays and very little in other wavelengths. It was thought that it could possibly be a neutron star, an extremely compact body weighing as much as the Sun but with a diameter of only about 20 kilometres. Some neutron stars have been observed as pulsars, which emit strong and regular pulses in the radio band, some of them many times every second. This is explained as a "lighthouse" effect, during which a beam of energetic particles emanates from near the surface of the rapidly rotating pulsar. The beam regularly "sweeps" the Earth, allowing observations to be made of the strong radio emission associated with this beam each tine. Pulsars are believed to be formed during violent supernova explosions.

Early last year, weak intensity variations (pulsations) were found to be present in the gamma- and X-ray radiation received from Geminga. Measurements showed that, at least in this respect, Geminga behaved like a pulsar. The derived period was 0.237 seconds, indicating that it turns on its axis just over 4 times per second.

But no radio emission has ever been observed from Geminga, even with the most sensitive radio telescopes. There is also no nebula around Geminga, as is the case with pulsars in the Crab and Vela Nebulae.

Measuring the Distance to Geminga

The problem was whether Geminga was a completely different object.

The crucial observation needed to solve this question was the measurement of the distance to Geminga. If it was a gamma- and X-ray emitting, rotating neutron star, it must be near.

On November 5, 1992, observations of the Geminga field were made by Alain Smette with the New Technology Telescope (NTT) at the La Silla observatory. He took 10 exposures, each of 15 minutes, during very good observing conditions. These images were then combined in the NTT image processing computer and immediately transferred by satellite data link to Milan, where Italian astronomers compared the new NTT image with the earlier images.

It became immediately obvious that Geminga (G") is moving, relative to the other stars in the field. The direction of motion is towards the North-East. The distance covered between January 1984 and November 1992 is about 1.5 arcseconds. In other words, Geminga moves with the unusually high speed of about 0.2 arcseconds per year so it will move a distance equal to the apparent diameter of the Moon (30 arcminutes) in just over 10,000 years. This is slow by Earthly standards but few stars move so fast so this is a certain indication that Geminga is a nearby object.

Assuming that the actual velocity of Geminga in the plane of the sky is equal to the mean velocity of other pulsars as measured by radio telescopes, that is about 100 km/sec, the distance to Geminga can be estimated as about 300 light-years, or about 70 times more distant than the nearest star known, Proxima Centauri. This is a very small fraction of the diameter of our Milky Way galaxy, of more than 100,000 light-years.

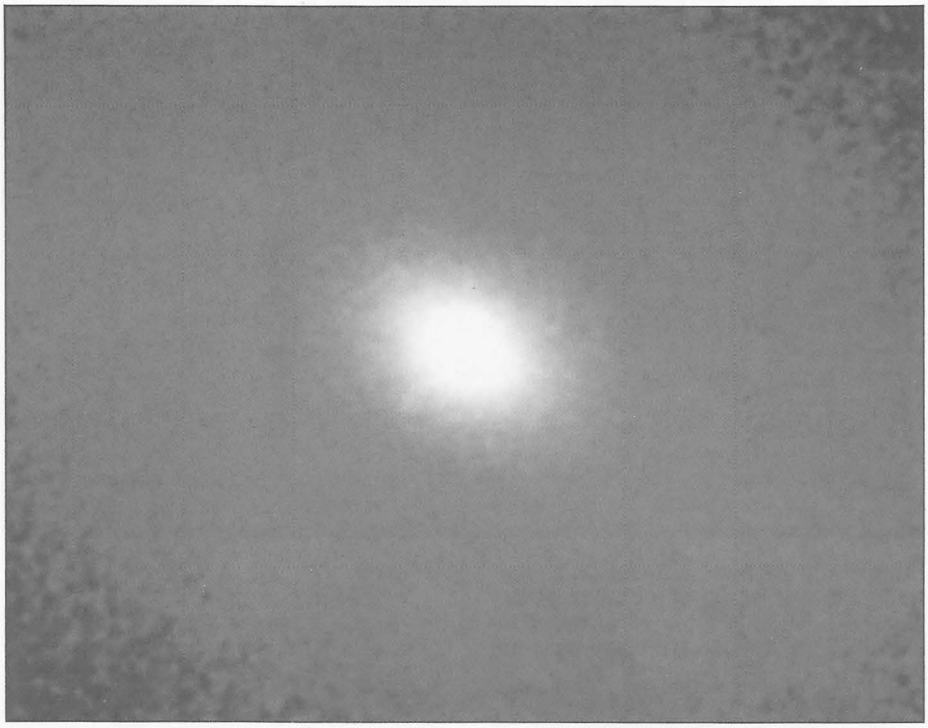
No other neutron star is known to be so close to us so Geminga is the nearest of its type. The reason that no radio-emission is recorded may either be because that its beam does not point in the direction of the Earth, or that it is a comparatively old and weak pulsar, possibly both.

Geminga is now moving towards the border between the constellations of Gemini and the Lynx, some 20° away from its present position in the sky. At the current speed it will cross that border in about half a million years so, until then at least, the present name will be appropriate.

The Core of Galaxy M32

The search for super massive black holes in the cores of galaxies is one of the primary missions of NASA's Hubble Space Telescope. By investigating both active and quiescent galaxies astronomers will have a better idea of the conditions and events which lead to the formation and growth of super-massive black holes.

New evidence has been produced that a black hole weighing 3 million times the mass of the Sun exists at the Centre of the nearby elliptical galaxy M32. This is based on images obtained with the Hubble Space Telescope (HST) which show that the stars in M32 become extremely concentrated toward the nucleus. This central structure resembles the gravitational "signature" of a massive black hole. The presence of a black hole in an ordinary galaxy like M32 may mean that inactive black holes are common to the centres of galaxies so M32 may prove to be an interesting "laboratory" for testing theories of the formation of massive black holes.



Compact Core of Galaxy M32

Hubble Space Telescope photograph of the central core of M32 taken on August 17, 1991.

The steady increase in brightness towards the centre of M32 is readily apparent, indicating that stars are strongly concentrated towards its nculeus, as if drawn into the centre and held there by the gravitational field of a massive black hole. Theoretical models suggest that the structure of M32 is consistent with a central black hole of 3 million solar mass.

The region shown In 175 light-years on a side at the distance of M32. The grainy appearance near the borders of the image is due to the Hubble Space Telescope resolving Individual stars within M32.

Tod R. Lauer/NASA

M32 is quite small and compact as elliptical galaxies go, containing roughly 400 million stars within a diameter of only 1000 light-years. At a distance of only 2.3 million light-years, M32 (the thirty-second object in a catalogue of non-stellar objects compiled by French astronomer Charles Messier in 1774) is one of the closest neighbours to our own Milky Way galaxy. It is a satellite of the great spiral galaxy in Andromeda, M31, which dominates the small group of galaxies of which our own Milky Way is a member.

M32 has been among the best candidates for a galaxy with a massive central black hole. The idea was first advanced in 1987 by Dr John L. Tonry of the Massachusetts Institute of Technology, and independently by Dr Alan Dressler of the Observatories of the Carnegie Institution of Washington and Dr Douglas O. Richstone of the University of Michigan. Their observations, made with ground-based telescopes, showed an abrupt increase in the orbital velocities of stars towards the centre of M32. This data led them to conclude that M32 must have a strong but unseen concentration of mass at its centre. A black hole at least several million times the mass of the Sun is the most likely type of object matching these characteristics.

However, ground-based images do not have enough resolution to detect the effects of a massive black hole on the structure of M32. The Hubble Space Telescope images, analysed by investigators on the WFPC imaging team, show the nucleus of M32 in clear detail. The density of stars in the nucleus appears to increase steadily towards the centre and show no sign of levelling off. These results are very similar to the predictions for what a massive black hole should do to the central structure of a galaxy.

M32 is the densest stellar system currently known to astronomers. Stellar density at the centre may be over 100 million times greater than the distribution of stars in the region of our own Sun. A visitor to a planet at the centre of M32 would see a starry night sky so saturated with stars that their combined light would be brighter than 100 full moons. The night would never get darker than mid-twilight on the Earth, so one could easily read a newspaper.

A black hole at the centre of M32 would have the paradoxical effect of stabilising the galaxy's nucleus because the stars orbit so rapidly around the black hole that they move past each other too quickly to be captured gravitationally, or collide. The black hole thus keeps the centre of the M32 galaxy "stirred up".

In the absence of a black hole the stars would move slowly enough to attract each other gravitationally. Collisions between stars would then become more frequent, and heavier, slower moving stars would sink to the centre of the galaxy, causing it to collapse.

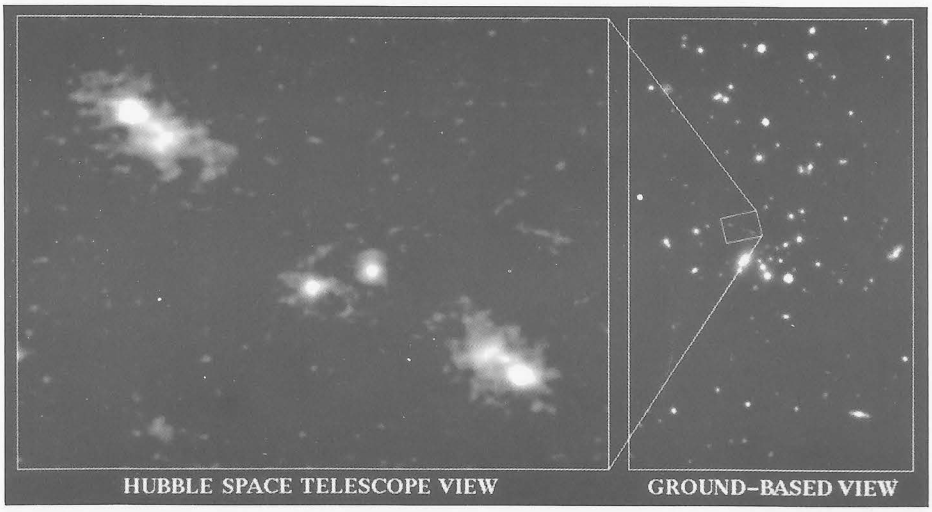
The fate of a collapsing core is uncertain. One possibility is that binary stars formed during a core collapse would provide enough kinetic energy to halt the collapse by transferring momentum to bigger stars. This would make the core rebound, like a rubber ball that has been squeezed and then relaxed. An alternative possibility is that a runaway margin of stars would occur during core collapse leading to the formation of a black hole in any case,. If so, this would rule out alternative explanations that don't require a black hole.

Which of these scenarios is correct? If the core is really unstable, one would expect to find evidence of merged and captured stars called "blue stragglers". HST has uncovered such stars at the core of a globular cluster, a much smaller aggregate of stars than M32.

The shape of the starlight distribution at the core would also be different from that which HST detects. Hubble images, instead, show that the population of stars in the nucleus is the same as that further out in the galaxy and that the shape of M32 remains constant into the centre. This indicates that a core collapse has not occurred recently.

M31 can be seen with the naked eye as a spindle-shaped "cloud", the width of the full moon, and its small companion M32 can be seen with a small telescope.

Another Gravitational Lens in Galaxy Cluster AC114



Hubble's wide-field camera has captured a mirror image of a distant galaxy beyond a huge cluster of galaxies located about 4 billion light-years from Earth.

The cluster acts as a natural lens, or magnifying glass, bending, concentrating and focusing the light from the distant galaxy into several images, each of which is bigger and brighter than otherwise would be the case.

"This rare combination of Hubble's powerful telescope mirrors and the natural 'telephon lens' will give new information on the nature of distant galaxies", said Richard Ellis of the University of Durham.

By studying how the natural lens bends the light, the amount and location of mysterious dark matter, thought to make most of the cluster's mass, may be deduced.

The unique combination has allowed astronomers to measure the bending power of the lens very precisely and has enabled them to determine the distribution of matter in the cluster regardless of whether or not it emits light.

The discovery was made while observing a cluster called AC114. Two six-hour exposures of the cluster revealed a striking pair of faint objects close to the centre of the cluster, each structure showing a perfect symmetry.

International Study of the Earth's Magnetic Field

A coordinated multi-mission effort in solar-terrestrial science is to be mounted over the next 4 years by scientists from the United States, Japan, Russia and Europe.

The Heads of Delegations to the IACG have approved a coordinated multi-mission effort which, in the 1990's, will involve up to 35 spacecraft in as many as 25 common scientific projects in solar-terrestrial physics.

Studies began with the launch of Japan's Geotail satellite in July 1992 and will continue with the planned launch next year of NASA's WIND spacecraft, Russia's 2-spacecraft Interball mission for launch in the Autumn of 1993 and ESA's Cluster and the SOHO missions in 1995. NASA's Interplanetary Monitoring Platform and the Japanese AKEBONO spacecraft are also expected to provide further data.

This new international approach will maximise the scientific return from this suite of missions to gain a greater understanding of the Earth's magnetosphere, the magnetic field that forms a "cocoon" around the Earth. Electrical and magnetic interactions involving the magnetosphere, the solar wind and interplanetary shock waves cause storms there which may create disturbances in the Earth's atmosphere, affecting communications, electrical power systems and spacecraft electronics.

The study not only embraces quiet electrical and magnetic conditions but also major impacts on the magnetospheric tail from changes in the solar wind, e.g. interplanetary shock waves, large pressure pulses and changes in the interplanetary magnetic field. Other severe tail instabilities generated within the magnetosphere itself include the storage and violent release of energy known as storms and sub-storms and processes of energy transfer between near-Earth and distant-tail regions.

Knots in a Distant Galaxy

The Hubble Space Telescope (HST) has revealed a chain of luminous knots in the core of the most distant known galaxy - one that existed in the infancy of the universe and is now more than 10 billion light years from Earth.

"These knots could be giant clusters of stars. If that is so, then each knot would contain about 10 billion stars and would be about 1,500 light years across", said Dr George Miley of Leiden University in the Netherlands.

An alternative theory is that the knots are gas or dust clouds caught in a "searchlight" beam of energy from a massive black hole hidden at the galaxy's core.

The galaxy's great distance from Earth indicates that it was formed only 1 or 2 billion years after the Big Bang, which marked the beginning of the observable universe. Most galaxies probably formed during this early epoch. The new photos, taken with the HST's wide field and planetary camera, reveal detail ten times better than photographs previously taken with ground-based telescopes.

The galaxy, designated 4C 41.17, is already known as a radio galaxy producing powerful, extended radio emissions. In the case of 4C 41.17 it is presumed that a massive black hole, rotating in the core of the galaxy, is producing twin jets of particles moving at enormous speeds. The energy from these jets could be the source of the radio emissions.

Images suggest that the high velocity particle jets compress gas and dust along their paths, triggering the formation of new stars. This would account for the elongated optical appearance of the galaxy. If this explanation is accurate, the knots along the jet paths would be clusters of stars in "enormous numbers, the products of the highly disturbed inner region of the primeval galaxy," Miley said.

It also is possible, said Miley, that the light photographed by the HST is not due to stars along the jet paths but rather comes from a disk of material surrounding the black hole which is being scattered off clouds of gas or dust. An active galactic nucleus of this description is called a quasar. It is hidden from optical view by a thick dust shroud which allows light to escape only along the radio or jet axis.

Hubble can help discriminate between these possibilities by further studies of the colours and other properties of these and similar objects. After the scheduled Space Shuttle servicing mission for Hubble in late 1993, HST can be used to carry out detailed studies of many galaxies at distances comparable with 4C 41.17.

"More than 50 are now known", said Miley, "Observing them with the renewed Hubble would provide us with an important new window through which we can glimpse the early history of our universe.

Marsquakes

Mars was once very active tectonically and may still be shaken by quakes daily, according to scientists studying Viking Orbiter photographs of the red planet's surface. Drs Matthew Golombek, W. Bruce Banerdt and David M. Tralli consider Mars to be more seismically active than the Moon, but less so than Earth.

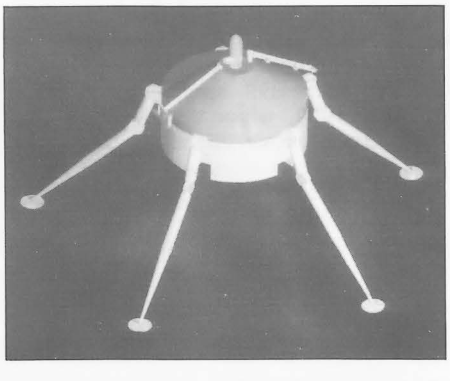
"Because Mars is smaller than Earth, little more than half the size, a magnitude 6 quake on Mars would have 10 times the effect it would on Earth", Golombek said. "Marsquakes of that magnitude may occur about once every 4 and a half years" he added. A Marsquake of about magnitude 4 might happen somewhere on the planet once a month on average. It would be detectable throughout the planet, because of its size and presumed structure. While Mars is less seismically active than Earth, their studies predict that about two Marsquakes of magnitude 5 or greater occur per year and about a hundred quakes of magnitude 3 or greater occur per year.

Tectonic features on Mars are found mostly around the Tharsis region, a large volcanic plateau with associated features that cover the entire western hemisphere of the planet. Tectonism there occurred mainly during two periods in the planet's history - the earliest possibly as long ago as 4-billion years and the most recent ending possibly less than one-billion years ago. Features formed during the first seismic period include many narrow graben or long ditch-like or trough features with faults along their sides. Also formed at that time was a system of concentric wrinkle ridges, larger graben and rifts, and the deep rift valleys of Mars' great 1,860-mile-long (3,000-kilometre) canyon, the Valles Marineris.

During the second period, tectonism caused an enormous set of radial grabens that extend up to thousands of kilometres from the centre of the plateau and rift zones of Valles Marineris, along with other prominent features.

MARSNET

One of four ESA future science projects, is a proposal for a network of surface stations on Mars to be part of a larger network provided by NASA. A decision on whether to proceed with this or to favour one of the three alternative proposals is expected in mid-1993.



SPACE PROBE DIARY

November 6 *Mars Observer*

Spacecraft subsystems continue to perform well. Instrument payload and payload data checkouts were continued as planned.

The instrument calibration flight sequence is to continue to November 17, 1992. The magnetometer and Gamma Ray Spectrometer instrument teams are receiving early cruise calibration data. The Mars Observer Camera "bakeout" to prepare the camera for operation will continue to December 26, 1992. New spacecraft activities will be minimal over the next few days.

The spacecraft is now about 12 million kilometres (7.5 million miles) from Earth, travelling at a speed of about 11,800 kilometres per hour (7,500 miles per hour) relative to Earth. Its heliocentric velocity is about 111,000 kilometres per hour (70,000 miles per hour).

November 20 *Mars Observer*

All spacecraft subsystems are performing well. A new flight sequence, primarily dedicated to radio science activities began on November 17 and will continue to December 14. Checkout of the Thermal Emission Spectrometer and completion of the laser Altimeter checkout have been performed. The Mars Observer Camera "bakeout" to prepare the instrument for operation will continue until December 28.

Until now, the spacecraft's solar panels have been oriented at a 60 degree Sun incidence angle to prevent excess power caused by the solar array's direct exposure to the Sun. A star-ephemeris table was uploaded on November 17, decreasing the Sun incidence angle by 5 degrees. The periodic changes will occur about once a week until January 2, 1993 and will cause the spacecraft's high-gain antenna to point directly at Earth.

The spacecraft is about 16 million kilometres (10 million miles) from Earth, travelling at a speed of about 14,500 kilometres per hour (9,000 miles per hour) relative to Earth. The spacecraft is travelling at a heliocentric velocity of about 111,500 kilometres per hour (70,000 miles per hour).

The second trajectory correction manoeuvre (TCM-2) has been rescheduled for February 8, 1993, to allow time to upgrade on-board flight software. TCM-3 has also been rescheduled for March 8, 1993.

November 28 *Dante*

A prototype walking robot, Dante, designed for possible future Mars missions is to descend into an active Antarctic volcano, Mt Erebus, on Ross Island and about 800 miles from the South Pole. Spider-like Dante is constructed of strong, light metals and can withstand temperatures of 150 degrees. It can navigate tall obstacles, using a newly developed laser-scanner providing a 350 degree field of view to provide warning of dangers and enable on-board computers to decide where to locate its feet.

December 1 *Clementine I*

Tests are progressing on the electronics needed for a 1994 launch on this joint SDI/NASA Project for a small spacecraft to observe the Moon and fly by a near-Earth asteroid. Lightweight instrumentation includes a 334 gram star tracker, a 600 gram inertial measurement unit and a 440 gram uv/optical wavelength camera.

December 1 *International Ultraviolet Explorer (IUE)*

IUE, which has had its lifetime extended on a yearly basis, will begin its 15th year of operations on 27 January next. A three-year programme was selected in 1991 for completion of a final high-priority programme to undertake the final calibrations and complete the development of the full IUE database and to establish final archives.

A run-down phase was envisaged for 1993 but it now seems likely that operations will be extended for a further two years, leading to a termination of the programme at the end of 1994.

7 December *Galileo*

Galileo passed about 68,000 miles of the Moon at 10:58 pm EST and within 190 miles of Earth at 10:09 am EST on 8 December. The pass increased the probe's speed by 8,280 mph, sending it toward the asteroid belt between Mars and Jupiter at about 87,190 mph. The pass of the atomic-powered, $1.4 billion spacecraft will also be used to calibrate the probe's instruments by using sensors and cameras to study and photograph the Earth and Moon.

Eight days after passing Earth, the probe will take a series of colour images of both the Earth and Moon which will then be made into a short film.

Galileo was launched from the space shuttle Atlantis on October 18, 1989, to begin a six-year, three-planet journey requiring the probe to go once past Venus and twice past Earth for the velocity-boosting gravity-assist flybys required to send it on to Jupiter.

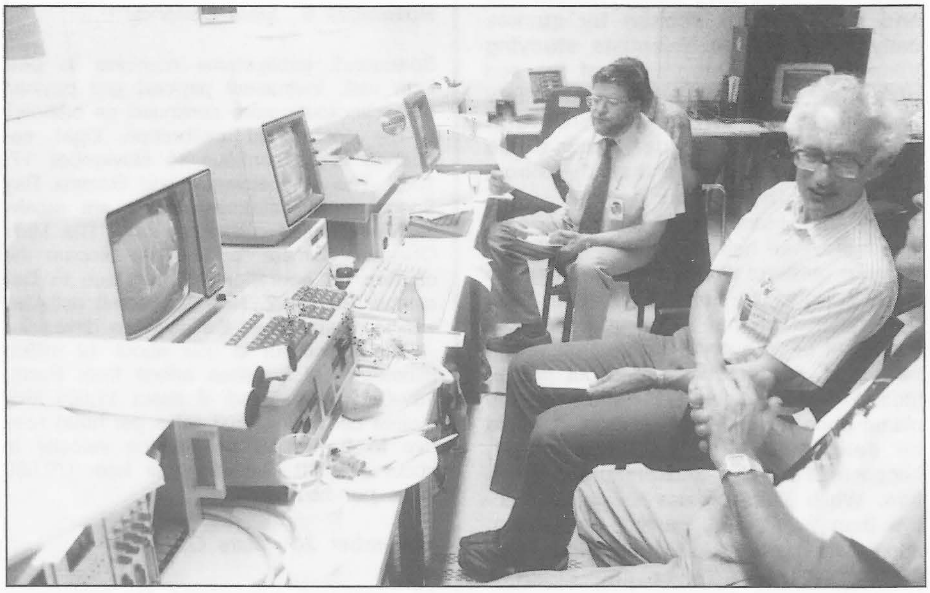
Jupiter, centre of a miniature solar system of 16 moons, is the largest planet orbiting the Sun, it is a world of lightning, centuries-old storms and deadly radiation belts. Galileo passed Venus and Earth in 1990, thus gaining enough speed to reach the asteroid belt. After passing within 1,000 miles of the asteroid Gaspra on October 29, Galileo returned to the inner solar system for a second flyby of Earth. Galileo will fly within 600 miles of the asteroid Ida on August 28, 1993 and on December 7, 1995 will flash past the volcanic moon Io at an altitude of just 600 miles, using that moon's gravity to help decelerate into the Jovian system, lining up on a trajectory that will carry it over the point where an entry probe will enter the atmosphere of Jupiter.

The spacecraft is due to drop the instrumented probe into Jupiter's atmosphere before the mothership orbits the planet in December 1995 for a 20-month tour. If it survies the entry, the probe's six instruments will begin radioing data to the Galileo mothership for relay back to scientists on Earth.

Close-up photographs of Jupiter are expected to be between 20 to 1,000 times better than those of Voyager.

A Triumph for Europe's Space Industry

The successful encounter of the Giotto spacecraft with comet Grigg-Skjellerup on July 10 1992 [1] after years of hibernating in space has provided the European Space Agency with unique and initially unexpected first-hand experience in staging a multi-object mission in the inner Solar System.



A look at the experiemnters' room, where magnetometer data are still coming in, just after closest approach to Grigg-Skjellerup.

BY DANIEL FISCHER

As no plans for a mission beyond Halley existed in 1986, little more could be done than change Giotto's orbit to lead back to Earth in 1990 and reconfigure the spacecraft a for a long and silent journey.

It took the help of NASA's 70 metre antenna of the Deep Space Network near Madrid to send the awakening commands to Giotto's Low Gain Antenna in February 1990. But only after five tense days did the spacecraft redirect its High Gain Antenna to Earth, allowing a detailed assessment of subsystems and payload. And despite the now-affirmed loss of the only camera on board as well as of two other key instruments, its overall health and the remaining payload were deemed suitable for a Giotto Extended Mission (GEM).

Using the Earth's gravity one month later to change Giotto's orbit without spending large amounts of fuel, the space probe took aim for its second comet, Grigg-Skjellerup. It was put in hibernation again for two years, and in May of 1992 the reactivation worked without a flaw. The encounter with Grigg-Skjellerup differed in most aspects from the exploration of Halley. As both the comet and Giotto travel in the same direction around the sun, their relative velocity this time was only 14 km/s, one fifth of the encounter velocity with the retrograde Halley. But the intercept took place at a greater distance from both the Sun, causing a shortage of electricity aggravated by the loss of Giotto's batteries, and of the Earth, making communication harder.

In order to guarantee the continuous operation of all seven fully or partly working science instruments, the decision was made to save power by operating without uplink during the 36 hours around closest approach. This choice proved to be a wise one as all instruments would return valuable and often surprising data on Grigg-Skjellerup, a comet that could be called the opposite of Halley. Grigg-Skjellerup's activity only at about 1/200th of that of Halley's being a scaled-down version of it. Thus Grigg-Skjellerup appeared as a much more compact source in space to the approaching Giotto than Halley had been. Early results of several instruments have already shown that Grigg-Skjellerup's nucleus was missed by no more than 200-250 km, setting a new approach record for a small body.

But to the missions controllers and engineers at ESOC, the GEM means more than yet another "textbook encounter". Giotto is "a triumph for Europe's space industry" states current Flight Operations Director Howard Nye: a robust spacecraft still of the era of the International Ultraviolet Explorer observatory and the Voyager space probes which continue their missions for already a decade beyond their design lifetimes. And it was also the first multi-object interplanetary mission ESA has performed (with science activities at Halley, the Earth and Grigg-Skjellerup), without having been planned as such when the spacecraft was launched by an Ariane rocket in 1985. In contrast to other deep space probes that require continuous or at least periodic communication with ground control, Giotto could be sent into total hibernation, waiting to be revived only when scientific challenges or money allowed it. The financing for the mission to Grigg-Skjellerup, for example, was secured only in June 1991 after ESA had transformed the optional programme in a mandatory one.

An approach like this could be an example for the future exploration of small bodies in the Solar System, and not only for ESA. After the cancellation of CRAF, NASA is left without a dedicated spacecraft for these kinds of objects which many planetary scientists consider crucial for the understanding of our past. A mission with multiple encounters of asteroids and comets by a Giotto class spacecraft could be a viable concept, which was indeed proposed in the 1980s under the name "Multi Comet Mission". As the scientific community were focused on CRAF at that time, this concept did not meet much support, but in the framework of NASA's new plans for less costly interplanetary exploration a resurrection seems possible.

Meanwhile there is also a chance that Giotto's mission is not over either. Having been hit by only three dust grains in the inner coma of Grigg-Skjellerup the spacecraft re-emerged in virtually the same state as before. Only a worn-out command decoder was lost, not necessarily as a consequence of the comet, and could be fully replaced by the back-up system. Just 15 minutes after closest approach, Howard Nye told the surprised audience at ESOC that there were detailed plans in the drawers for another mission extension. A trajectory correction on 21 and 23 July 1992 (followed immediately by a third hibernation phase) used some 10 kg of fuel to redirect Giotto so that it will return to the Earth's vicinity in 1999.

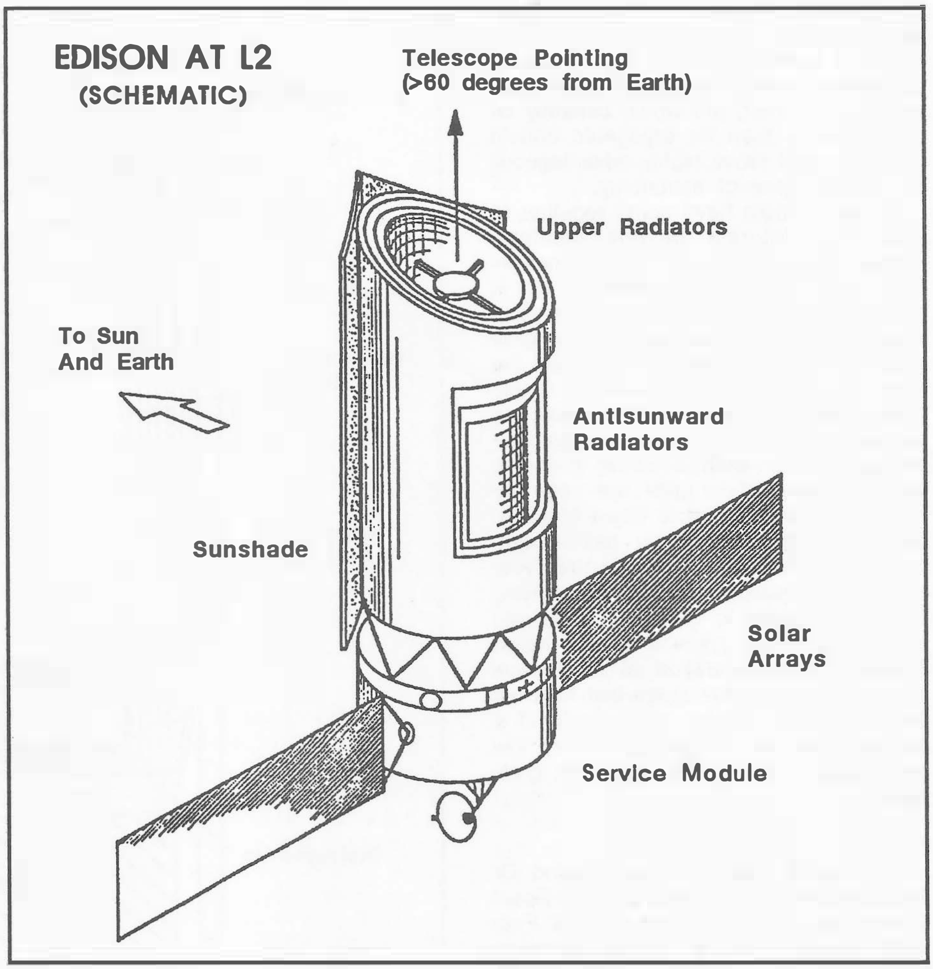
While there is considerable confidence in Mission Control that the spacecraft's health would allow for another assignment even after 15 years in space, the main constraint is fuel. According to Giotto's flight dynamics specialist Trevor Morley there should now be 4 kg left, but with an uncertainty of +/- 3 kg. Whether a third comet could be reached with this reserve depends on the availability of a target on a suitable orbit and on the distance by which Giotto will miss the Earth on July 1, 1999. If this distance is greater than 300,000 km, the additional fuel needs could be "far in excess" of what is left. But if the orbit on which Giotto was set this 23 July ultimately brings it closer to the Earth, there could be a possibility for another scientific mission with this most remarkable spacecraft. Only after another successful awakening of Giotto in early 1999, when the distance from Earth drops below 25 million kilometres, can ESA decide whether to risk it again, though the intent would have to be declared in 1997 - when the training for another generation of operators would have to start.

Reference

1. ***Spaceflight***, September 1992, p.304.

Passively Cooled Space Telescopes for Infrared Astronomy

AFTER a dearth of flight opportunities since the mid 1980s, infrared astronomers are looking forward to important space missions in the 1990s. The European Space Agency's infrared Space observatory (ISO) is expected to be launched about 1995 and in the USA the influential Bahcall committee recently backed the $1.3 billion Space Infrared Telescope Facility (SIRTF) (see *Spaceflight* Vol. 32, p.169-171, 1990) as a NASA priority. Although it has suffered many years of delay, and its design is still being modified in an attempt to reduce costs, SIRTF may be launched around the year 2000 to form the last of NASA's "Great Observatories". However, even as these missions develop, a group of American and European astronomers are looking beyond ISO and SIRTF to the next generation of infrared space missions. What is more they are investigating an innovative solution to the issues which limit existing designs for infrared astronomy satellites.



BY J.K. DAVIES
ROYAL OBSERVATORY, EDINBURGH

Infrared Astronomy

The infrared region of the electromagnetic spectrum, broadly speaking the wavelength range from 1 micron to 1 millimetre, is of interest to astronomers for a variety of reasons. For example an important source of infrared emission is cool material such as interstellar dust and shells around very young stars. Furthermore infrared wavelengths penetrate clouds of interstellar dust which totally block visible light, and this allows astronomers to peer deep into the dusty regions of space where star formation occurs. Many molecules have important spectral features in the infrared, making it possible to examine the chemical composition of interstellar gas and dust. On a grander scale cosmologists want to study the light from the early Universe that has been shifted into the infrared by the expansion of the Universe since the Big Bang.

Infrared astronomy is possible from the ground, but only through a limited number of wavelength windows, and the sensitivity of ground based telescopes is limited by the intense infrared emission that arises from the warm atmosphere above the observatory and from the telescope structure itself. These factors led to the development of the US/UK/Netherlands Infrared Astronomical Satellite (IRAS) which was launched in 1983. IRAS was based on a 60 cm telescope surrounded by a toroidal tank of superfluid helium. The supercold liquid helium kept the entire IRAS telescope at a temperature below 10K (-263°C), greatly reducing the infrared emission from the telescope. By removing this background radiation IRAS was able to survey the sky with unprecedented sensitivity during its 300 day mission.

Helium Cooling

The IRAS mission was short because the helium coolant was boiled away by heat leading in through the satellite's outer skin. This placed a very definite limit to the lifetime of the mission, once the helium coolant was gone the telescope began to warm up and the mission was effectively over, even though the spacecraft itself remained operational and under full control. Since ISO and SIRTF will also use telescopes cooled by the gradual evaporation of liquid helium, they too have finite lifetimes. ISO is expected to remain operational for about 20 months, the larger SIRTF mission was originally planned to have a life of about six years, although a smaller, cheaper design might not last so long. Neither satellite is equipped for in-flight replenishment of its cryogenic coolant and so their missions cannot be extended, no matter how successful they prove to be.

As well as limiting their lifetimes, helium cooling imposes other constraints on astronomical satellites. One of these is that the mass and volume of the cryogen tanks restrict the size of the telescope that can be carried (IRAS was about two metres in diameter but its main telescope mirror was only 60 cm across). The telescope for ISO, to be launched a decade later, will also have a 60 cm diameter mirror. The SIRTF, which will be launched five or more years later still, will have a mirror less than one metre in size. Although improvements in detector technology can make up for some of the restrictions of small telescopes, these statistics can be compared with the increase in collecting area achieved between the 45 cm International Ultraviolet Explorer (1978) and the 2.4 metre Hubble Space Telescope (1990).

Passive Cooling

Until recently infrared astronomers

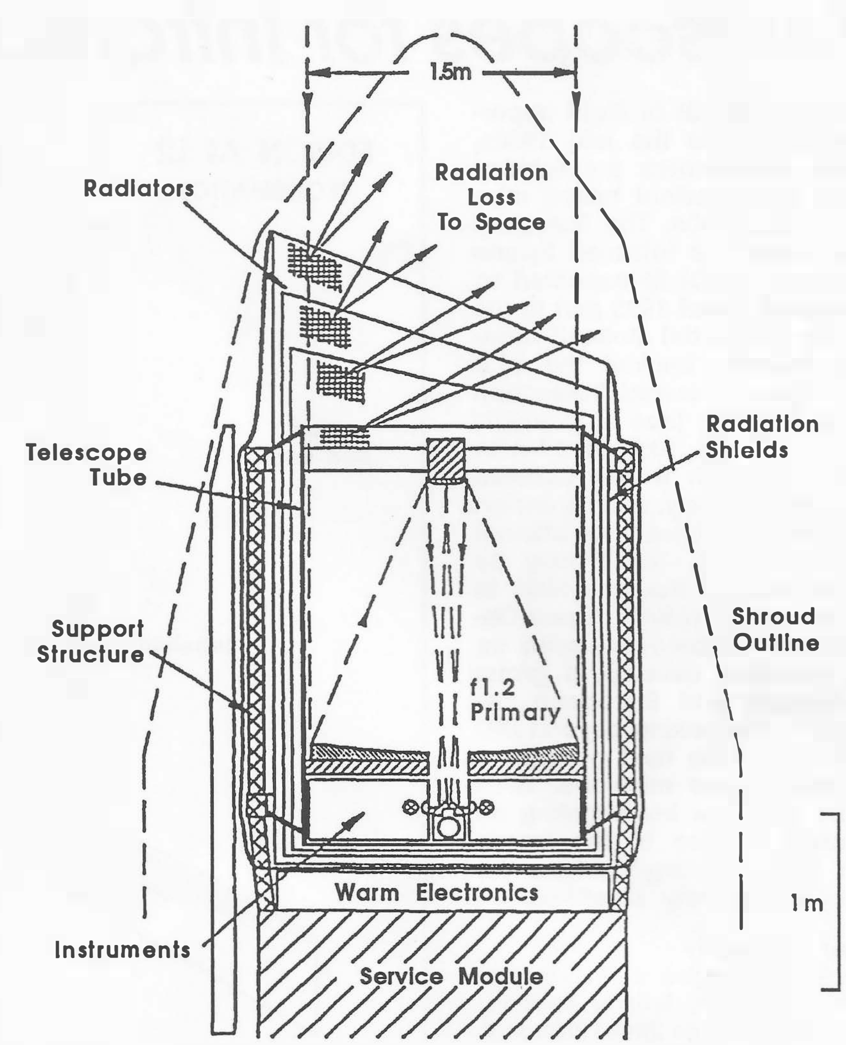
accepted the use of relatively small mirrors because cryogenic cooling has advantages, not the least being that it is simple, reliable and can keep a telescope very cold indeed. None the less, interest has been growing in the idea of developing an infrared satellite with no cryogens, but which would carry a telescope cooled just by radiation to cold space. Unencumbered by tanks of helium, such a spacecraft could carry a telescope which might be rather warmer, but would certainly be much larger, than its cryogenic cousin and this might prove highly advantageous for certain types of astronomy.

Several factors have come together to encourage interest in this concept. Firstly IRAS confirmed earlier results from rocket flights that the infrared sky is not truly 'black'. Warm dust throughout space gives the sky a faint infrared glow and, just as the daytime sky blots out the stars in visible light, this natural background glow limits the sensitivity that can be achieved by any infrared space telescope, however cold. Secondly it seems that faint infrared sources are very numerous and so appear to blend together, causing what astronomers call 'source confusion'. The only solution to this problem is a telescope with better resolving power (the ability to see fine detail) and to achieve this requires a bigger mirror. Thirdly a new generation of mechanical coolers are being developed that hold out the promise of cooling small parts of a satellite, such as detectors, to very low temperatures without the need for cryogens.

POIROT

With these developments in mind Dr Tim Hawarden and a team from the Royal Observatory, Edinburgh proposed a Passively Cooled Orbiting Infrared Observatory Telescope (which has the delightfully European acronym of POIROT) to ESA for consideration in its 1989 competition for the next 'medium sized mission' M2. POIROT was based on a development of the ISO payload module, but with the superfluid helium tank removed and replaced by a 1.5 metre diameter telescope mirror. Nested around the mirror were a series of shields that would have been cooled by their own radiation to space. The reduction of heat leaking inwards would allow the telescope to cool, also by radiation to space, to a temperature somewhere between 40 and 60K (-223° to -213°C). Although warmer than the ISO telescope, such an instrument would have been able to make many astronomical measurements in the 3-30 micron wavelength range. To cool the detectors of the scientific payload Hawarden envisaged the use of closed cycle coolers such as those developed for the ATSR experiment on the European ERS-1 Earth observation satellite. POIROT would have been placed in a highly eccentric Earth orbit so that the heat load falling on the satellite from the Earth would be minimised. Higher, circular, orbits in which Earthshine would be further reduced were ruled out by the ESA requirement for a satellite that could share an Ariane 4 launch to reduce costs. POIROT

POIROT IN ARIANE 4 TYPE 02 SHROUD



would have carried scientific instruments such as infrared cameras and spectrometers whose design byword would be 'simplicity'. With this approach it was hoped to develop a satellite that would cool to a usefully low temperature and operate for long periods without the ever present countdown to the final evaporation of helium coolant that hangs over ISO and similar missions.

Edison Satellite

ESA decided not to proceed with the POIROT concept when it selected its candidates for the M2 mission, but the seed that passive cooling might show promise for space astronomy had been sown. Dr Harley Thronson, an astronomy professor from the University of Wyoming who had been a visitor at Edinburgh during the development of the POIROT proposal, decided to explore the idea further without constraints of cost and size placed by the ESA rules for its M2 mission. Thronson, in co-operation with the POIROT team at Edinburgh, scaled up POIROT to a conceptual design for a satellite carrying a passively cooled telescope with a mirror 2.5 metres in diameter. Thronson christened his proposal Edison, after the American inventor who detected infrared radiation from a celestial body during experiments in 1878.

Edison would be large and expensive to develop so it is hoped to propose it as an international project. With its joint US/Europe heritage, the Edison team hope that the proposal will develop into a transatlantic cooperative project which might expand to include Japan or some of the members of the new Commonwealth of Independent States. if this can be done Edison could be launched early in the next century to pick up the torch of space infrared astronomy that was lit by IRAS and will by then have passed from ISO to SIRTF.

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The Author

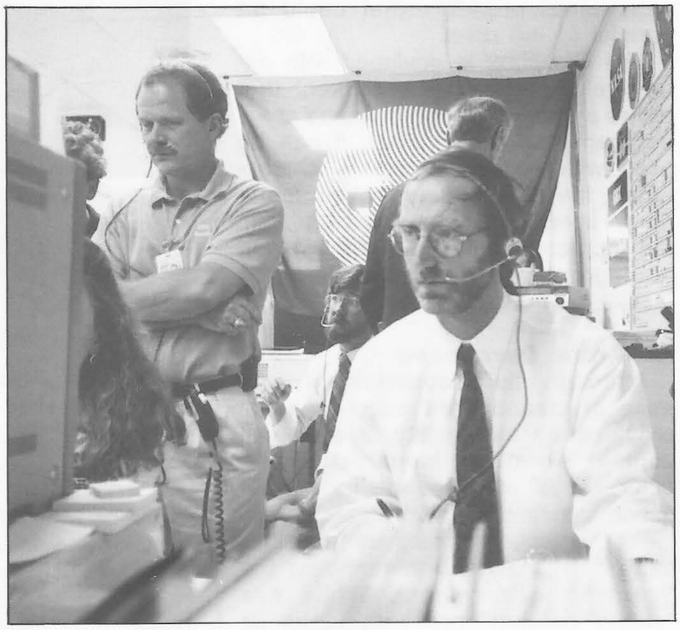
Dr John K. Davies is a Fellow of the Society and a member of the POIROT/Edison team.

Glovebox in Orbit

ESA/NASA Glovebox: A Versatile USML-1 Experiment Facility

When the Space Shuttle USML-1 flew on June 25, 1992 it was carrying aboard a general purpose experiment facility known as the "Glovebox" (GBX), which enabled scientists to perform materials science, fluids and combustion experiments safely without contaminating the closed environment of Spacelab and endangering the crew.

The Glovebox was designed, developed and manufactured by Bradford Engineering, The Netherlands and Brunel Institute for Bioengineering, UK under ESA Contract No 9209/90/NL/JS under the control of Mr Hartmut Helmke as Project Manager. This co-operation enabled the developers to comply with the tight schedule for USML-1 mission planning. In twenty-two months the project team produced three functioning bread board models, one engineering model and the flight model with all associated stowage items required for the mission. One bread board was modified and upgraded for crew training in the Payload Crew Training Complex (PCTC). In September, 1991, the flight hardware Glovebox together with its ground test support equipment completed its extensive acceptance testing at ESTEC, Noordwijk, The Netherlands and was flown to Kennedy Space Center for integration with Spacelab and the Space Shuttle.



Dr Ian A. Sutherland in the Glovebox Operations Area of Payload Operations Control Center, NASA, MSFC. *NASA*

BY DR IAN A. SUTHERLAND & PROF HEINZ WOLFF[1], HARTMUT HELMKE & WERNER RIESSELMANN[2], MIKE NAGY & EDUARD VOETEN[3] AND ROGER CHASSAY[4]

Background

The Glovebox concept was developed in 1981 by Professor Heinz Wolff of Brunel Institute for Bioengineering (BIB) as a containment facility for life sciences. It was designed to contain micro-organisms and allow payload scientists to prepare and fix biological samples through glove ports without allowing any leakage of toxic chemical vapours into the Spacelab atmosphere.

Air was circulated in closed loop mode through two separate banks of filters, capable of removing sub-micron particles through a HEPA particle filter and vapours by absorption on activated charcoal. This, combined with the "sealed box", which was always maintained at a negative pressure in relation to the cabin atmosphere, would doubly ensure that nothing could escape. If, for any reason, a glove broke or was torn, then the unit would switch instantly to "open mode" where Spacelab's air would be sucked in through the opening and pass through both sets of filters before being returned to the Spacelab atmosphere again. The velocity of the air into the GBX through any leak was sufficiently high (>1 m/sec) to ensure that nothing could escape without passing through the filtration system.

The first space qualified Glovebox built using this basic concept was manufactured for ESA's BIORACK by Fokker, an Aerospace Company in The Netherlands, and has flown twice on Spacelab: in 1985 on D1 and in January, 1992 on IML-1.

Evolution of the USML-1 Glovebox

The USML-1 Glovebox has been specifically designed as a general purpose experiment facility with a number of new features. The story began in late 1989 when ESA approached Bradford Engineering, a Dutch Aerospace company and Brunel Institute for Bioengineering to see if they could develop an advanced biological safety cabinet with improved and interchangeable filters (the BIORACK Glovebox has a single large filter which was not interchangeable).

It was only in August 1990, midway though the Phase B Critical Design Review (CDR) that NASA formally reviewed the design for inclusion in the Space Shuttle USML-1 Mission coming to a "no exchange of funds" agreement with the European Space Agency (ESA), whereby use of the Glovebox by NASA was traded for flight opportunities for ESA. Considerable changes were made at this stage as the requirement was for general material science usage rather than a biological one. While the principle remained the same, a proposed air lock was discarded and a video display recording system was added together with many requirement changes.

NASA understandably is very safety conscious, to the extent that before any scientist can perform an experiment involving the potential leak or spillage of toxic chemicals or products of combustion they have to convince NASA safety personnel that they have the appropriate levels of containment, as the experiments must still be safe despite any two simultaneous failures. NASA scientists were delighted, therefore, to have access to a facility which immediately supplied them with levels of containment, monitoring and imaging that they required. The experiments immediately became simpler to develop, less expensive, and had a shorter development lead time.

Special Features of the USML-1 Glovebox

The USML-1 Glovebox offers investigators a new capability to test and develop science procedures and technologies in microgravity. It enables crewmembers to handle, transfer, and otherwise manipulate materials in ways that are otherwise impractical in the weightless environment of space.

The Glovebox has an enclosed compartment that offers a clean working space and minimises the risk of contamination to either the Spacelab or the experiments samples. It provides two types of containment for

1 Brunel Institute for Bioengineering, UK.
2 ESA/ESTEC, Noordwijk, The Netherlands.
3 Bradford Engineering, Putte, The Netherlands.
4 NASA George C. Marshall Space Flight Center, Huntsville, Alabama, USA.

small quantities of materials: physical isolation and negative air pressure differential between the enclosure and the rest of the Spacelab working area. An air-filtering system also protects the Spacelab environment from experiment products that could be harmful to the crew.

The Glovebox is equipped with extensive photographic equipment that allows a visual record to be made of experiment operations. Also, it can be used with accelerometers to characterise the low gravity environment. Many investigations will benefit from the increased crew involvement and photographic/video capabilities the facility permits.

Hardware Description

Although fluid containment and ease of cleanup are major benefits provided by the facility, it also can contain powders, bioparticles and other debris produced during investigation operations. Even toxic, irritating or potentially infectious materials can be prevented from entering the Spacelab environment. While this "safety cabinet" prevents leaks or spills into Spacelab, it also protects samples from contamination when experiment procedures call for containers to be opened.

The facility provides the following services to microgravity investigations: a large viewing window atop the cabinet, experiment mounting and positioning equipment, real-time downlink of experiment video and housekeeping data, electrical power, partial temperature control, a time-temperature display, lighting and cleaning supplies. It has six video camera heads* (three black-and-white and three colour) to record experiment operations, and the behaviour of specimens, a backlight panel, a 35-mm camera, and a microscope that offers high-magnification viewing and the capability to record images when used in concert with the video or still cameras.

The crew manipulates samples or experiment equipment through three doors: a large central door though which experiments are placed in the Glovebox and two glovedoors. The glovedoors are located on each side of the central port and serve several functions. When an airtight seal is required, the crew insert their hands into rugged gloves attached to the glovedoors, and no airflow occurs between the enclosure and the Spacelab. If the investigation requires more sensitive handling than allowed by the rugged gloves, the crew may don surgical gloves and insert their arms through a set of adjustable cuffs. Each of the glovedoors also provides a viewport for the facility's charge-coupled device (CCD) cameras, and they are reversible so that the cameras and glove ports can be mounted high or low.

* Only four can be connected at any one time; two can be connected to the Spacelab VAS and one to an on board video recorder. There is a foot switch to toggle between cameras.

Dr Ian A. Sutherland demonstrating the engineering model Glovebox to former astronaut Byron Lichtenberg in the Payload Operations Control Center (POCC), NASA, MSFC. *NASA*

General operations require the crew to unstow experiment modules and specimen, move them to the Glovebox, and place them inside. Most of the experiment modules have magnetic bases or strips that hold them to the metal floor of the Glovebox work area. Others attach to a laboratory jack that can position the module at a chosen height above the work area floor for optimal photography. Equipment also may be bolted to the left wall of the working space or attached outside the facility with Velcro™ fasteners.

Once the experiment equipment is secured, the crew will proceed with operations specific to a particular investigation. following the investigation, the crew will clean up any spills or leaks in the workspace, reassemble the hardware if necessary, and move it back into stowage. They will also store any samples that must be preserved for postflight analysis.

European Space Agency representatives in the Glovebox mission support team at the Payload Operaitons Control Center (POCC), NASA, MSFC. *Left to right:* Mike Nagy, Hartmut Helmke and Dr Ian A. Sutherland. *NASA*

Glovebox Experiments

The Glovebox experiments on the First United States Microgravity Laboratory (USML-1) mission fell into four basic categories: fluid dynamics, combustion science, crystal growth, and technology demonstration. Crewmembers conducted 16 investigations that tested or demonstrated microgravity science theories, procedures and hardware across a broad range of the four categories. Some of these investigations also provided information to other USML-1 experiments for immediate use during the mission to refine experiment operations.

Seven fluid dynamics investigations focused on basic fluid phenomena and how they affected materials processing. In addition, these investigations demonstrated technologies that may enhance the study of fluid behaviour in space. The investigations examined factors influencing the behaviour of liquids in reduced gravity: the causes of surface movement in free liquids, the degree of contact between a liquid and its container, bubble formation and movement, and the comparative strength of subtle forces during fluid processing. Techniques for deploying liquid drops in microgravity were also demonstrated.

Three combustion science investigations examined the role of subtle forces that are usually masked by Earth's gravity. These studies sought to increase knowledge of how combustion occurs in space - whether it results in smouldering or open flames. Findings may be applicable to operations that produce flames and to improved spacecraft safety features.

The Glovebox also supported three investigations that grew zeolite, L-Arginine phosphate and protein crystals. These activities tested and refined techniques for growing crystals in space.

In the realm of technology demonstration, one investigation assessed whether a material used in medical implantations could be produced effectively in space. Another demonstrated a new means of gathering microgravity accelerometer date, while a third tested a method for creating fine particle clouds.

Payload specialist Lawrence J. DeLucas works at the multipurpose Glovebox in the science module aboard the Earth-orbiting space shuttle Columbia. Provided by ESA, the Glovebox enables crew members to handle, transfer and otherwise manipulate materials in ways that are impractical in the open science module. At least 16 experiments were accommodated in the Glovebox during this 14-day record-setting mission. *NASA*

Post Mission

NASA personnel were delighted with the performance of the Glovebox when it flew on the longest Shuttle flight so far from June 25 - July 9, 1992. It not only performed without a hitch, but it significantly contributed toward two other experiments: one requiring the full containment facilities for fixing Generic Bioprocessing Samples with Formaldehyde solutions and the other using the GBX microscope and downlink video to visualise their samples.

Another unexpected bonus for NASA mission managers and scientists was the unexpected acclaim the Glovebox received from the American public. Nearly half the TV and press coverage of the mission featured the Glovebox and its experiments in some way. Each day there was something new and exciting happening and the multiple Glovebox video cameras helped to give new meaning to "hands on" science in space.

Crew Debriefing

The crew were extremely complimentary toward the Glovebox during the debriefing meetings. They made several suggestions on how to improve its versatility and human factor interfacing. For example, it was never anticipated that the missions specialists would spend many hours each day for 13 days with their arms in the gloveports; the cuffs proved too inflexible for long term operations. Even during the mission a more flexible approach to handling samples in the Glovebox was adopted, by cutting the hands off a set of gloves, to turn them into sleeve or arm seals, while the hands were protected by the normal surgical gloves. This improvisation gave a more flexible arm movement and a better seal than the cuffs.

The Future

In an interview for the "Today in Space" programme, the NASA Project Manager for the Glovebox, Mr Roger Chassay said "NASA's extremely pleased with the use of the Glovebox on this mission. In fact it has been a workhorse in conducting 16 experiments. We're furthermore looking forward to the use of a similar type device that would be compatible with the orbiter Mid-deck, somewhat different from this Spacelab Glovebox, so that we'd have the capability to fly a device like this on virtually any Shuttle flight when it's needed".

NASA Program Manager Joel Kearns in a live interview on the same programme was even more enthusiastic: "We're very pleased with the performance of the GBX on this Mission. You know we set out to use the Glovebox as a laboratory workbench on orbit with our researchers on the ground and we couldn't be more pleased. After this mission NASA will be negotiating with the European Space Agency to gain access to the same Glovebox for the second US Microgravity Mission (USML-2) which we see coming up in 1995. In the future on Space Station Freedom we will be doing similar operations and experiments on a Space Station provided Glovebox known as the Material Science Glovebox. You'll be seeing that come up as early as crews get to Space Station Freedom, so watch for it!"

USML-1 therefore appears to have been the proving ground for the Glovebox as far as NASA is concerned. By providing a Glovebox in the Orbiter Mid-deck experiment turn-a-round time will be considerably reduced and space science will become much more accessible and affordable to both the commercial and research communities.

Acknowledgements

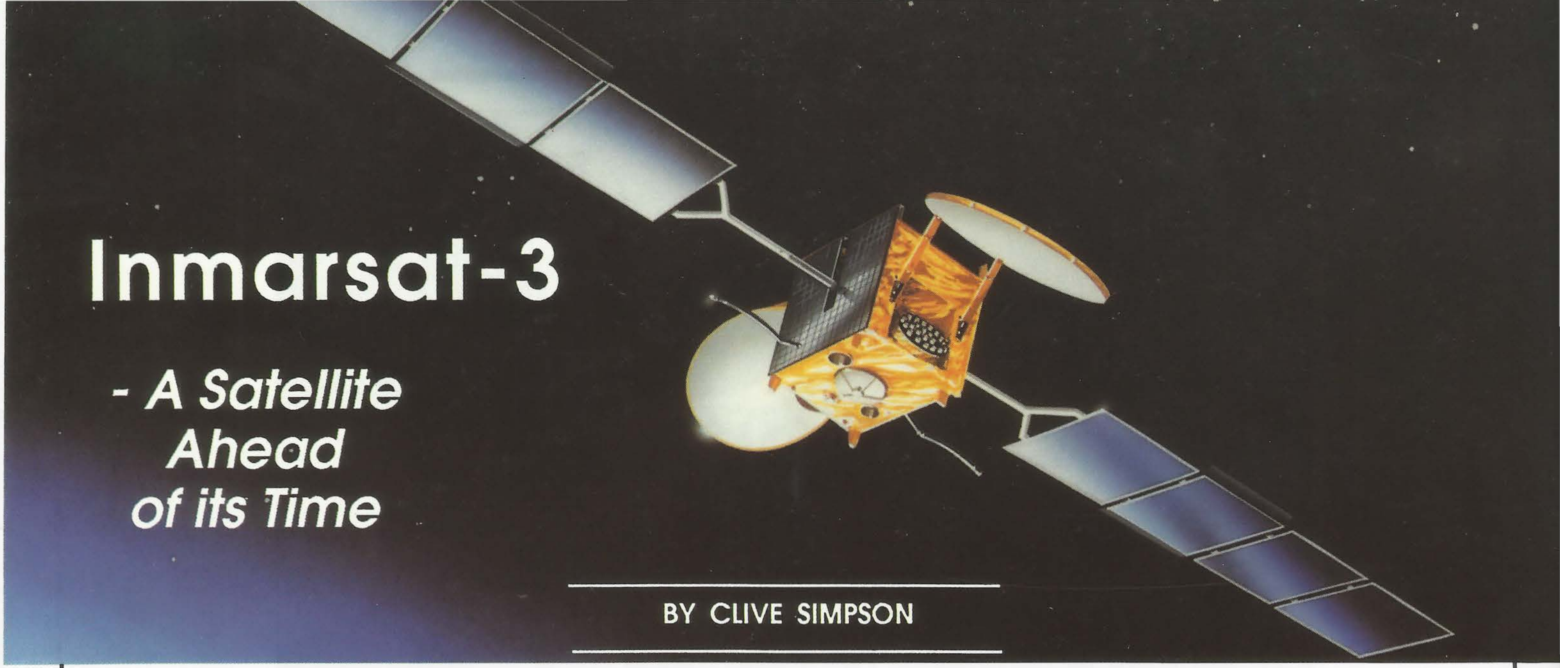
The authors would like to acknowledge the truly international cooperation and team spirit which has helped make this Mission so successful; particularly the efforts of the staff at Bradford Engineering, Putte in The Netherlands and at Brunel Institute for Bioengineering, in the UK, who have spent many a night hour keeping the programme on schedule.

Special thanks are due to Dr Jim Kingdon of the European Space Agency who conceived the project and set up the first feasibility studies.

Special appreciation is expressed to the Glovebox Project Team at NASA's Marshall Space Flight Center for their willingness to provide supplemental engineering, environmental testing, and special parts to keep the project on track.

Special thanks are also due to the eighteen members of the Glovebox mission support team who endured numerous simulations and the longest Space Shuttle Mission, 24 hours a day in three shifts, and maintained an excellent spirit throughout.

Finally, acknowledgements would not be complete without recognising the extreme effort and dedication of the crew in not just completing their numerous tasks in orbit, but doing so in such an interactive manner with scientists on the ground. We are also grateful for their constructive comments which will help us provide even more versatile equipment in the future.



Inmarsat-3

- A Satellite Ahead of its Time

BY CLIVE SIMPSON

Artist's impression of Inmarsat-3. Matra Marconi Space (UK) is responsible for the communications payload. The first satellite is scheduled for delivery in 1994. *Matra Marconi Space*

The most technically advanced satellite in the world. That is quite a claim, but one which can be made justifiably by the team of British engineers currently developing the new communications payload for Inmarsat's third generation satellites, Inmarsat-3.

Already the world leader in provision of satellite communications facilities for mobile maritime and land-based users, the multi-national Inmarsat is one of the space industry's most prestigious customers.

Comprising some 65 national signatories, Inmarsat provides worldwide mobile communications services to more than 11,000 ships and an increasing number of aeronautical and land mobile users.

For the UK arm of Anglo-French company Matra Marconi Space it was therefore a major achievement at the beginning of 1991 when the company was selected - in partnership with GE Astro Space of the United States - to provide the space segment of the new Inmarsat system that will take operations into the 21st century.

Validation Programme

The Inmarsat-3 programme provides for the delivery of four satellites to be launched from August 1994 onwards. These third generation satellites will be located in geostationary Earth orbit, providing mobile communications around the globe.

The programme itself represents a major technical challenge. The innovative Inmarsat-3 payload design concept requires the development of many new items of equipment, each of which will meet a level of performance, mass and power economy never before achieved. For this reason a Technology Validation Programme was conducted prior to the final contract award.

This exercise concentrated on demonstrating the required levels of performance from the key areas of technology in the payload design.

In particular, the Solid State Power Amplifiers (SSPAs) - a development of ESA work carried out at Matra Marconi Space's Watford site - were required to deliver state-of-the-art performance in a compact, low-mass, electrically efficient design.

Similarly, the L-band antennas, designed at Portsmouth, are new in concept and needed to demonstrate their performance requirements.

The aims of the Technology Validation Programme were successfully achieved on schedule and the contract signed in April 1991.

Spot Beams

The increasing demand for satellite communications channels over the next decade is such that it is essential to maximise the effectiveness of every satellite launched.

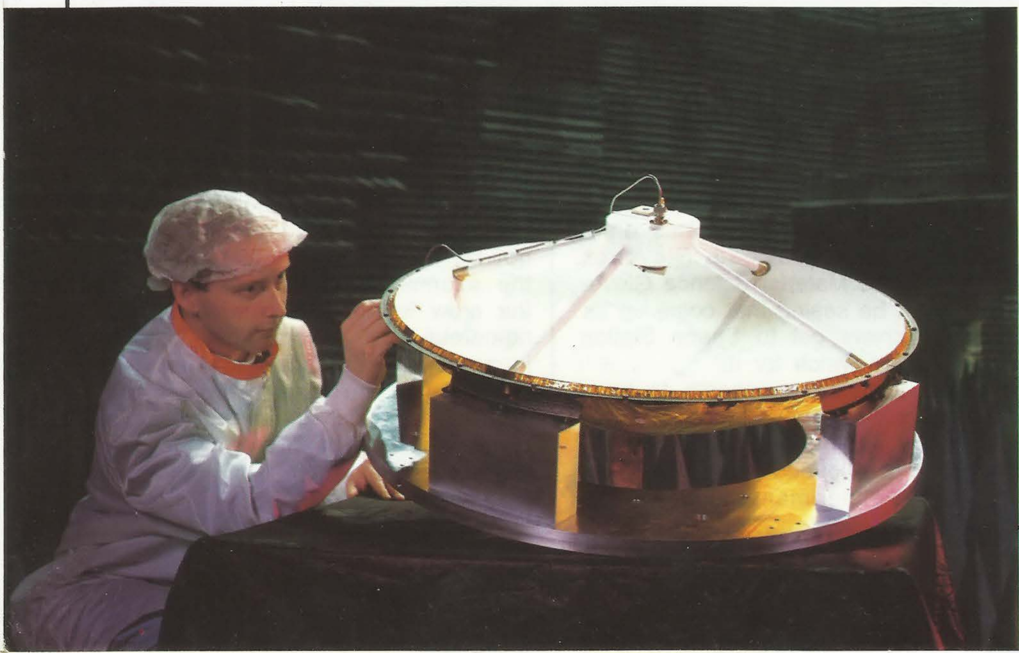
since the world's population is not evenly spread over the Earth's surface, the old 'global' coverage beams of the earliest communications satellites wasted a large percentage of carrying capacity, 'illuminating' areas of the globe where no demand existed.

The solution is to provide spot beams focused on areas where demand is highest. This is not new, but the inmarsat-3 payload goes much further, allowing the satellite's communications carrying capacity to directly match the global demand distribution, maximising the revenue earned by each spacecraft.

Although in such a scenario the beam patterns and power levels are different for different orbital locations, the Inmarsat payload possesses the flexibility to cope with the different traffic demands and can be reconfigured in orbit if the need arises to move a satellite from one location to another.

The communications payload consists of two independent transponders. A forward transponder converts C-band signals from fixed Earth stations to L-band signals which are transmitted to mobile users. The return transponder receives the L-band signals from the mobile users, converting them to C-band signals for

Inmarsat-3 navigation antenna under test. *Matra Marconi Space*



transmission back to the fixed Earth stations. The Earth stations connect the mobile users to the public switched network.

The payload also features a navigation package, an L-band antenna for global position determination.

Technical Challenge

The end of 1992 saw the conclusion of the development phase with production of flight equipment beginning in the new year.

As well as presenting a major technical challenge, the magnitude of the design and manufacturing programme is impressive - some 600 individual pieces of equipment are being built, of which 400 will be produced by Matra Marconi Space.

Most of these are state-of-the-art - from world-beating SSPAs, frequency generators and innovative antennas developed at Portsmouth, and power supplies developed at Velizy, France, to low noise amplifiers developed at Watford.

The first set of flight model equipment will be integrated into the first flight payload at Portsmouth and then delivered to GE Astro Space in the United States in the autumn of 1993. Subsequent flight payloads are to follow at the rate of one every four months.

Project manager, Peter Clipson: "Naturally when embarking upon a challenge of this magnitude it is not plain sailing all the way. Many technical problems have been met and solved, and inevitably the remaining activities facing the project team will continue to present challenges as the programme proceeds".

Electrical Ground Support Equipment (EGSE) for Inmarsat-3 payload, Portsmouth. *Matra Marconi Space*

Inmarsat-3: characteristics

Body dimensions	2.1 x 1.8 x 1.7 m
Solar array span	16.7 m
Spacecraft mass (dry)	772 kg
Payload mass	150 kg
DC power	2300 W
Design life	13 years
Frequency bands	L (mobile links) C (feeder links) L (navigation)

Inmarsat-3 navigation antenna. *Matra Marconi Space*

Inmarsat-3 engineering payload model under test on the Antenna Test Range, MMS, Portsmouth. *Matra Marconi Space*

Claude Nicollier to Fly His Second Shuttle Mission

ESA's astronaut Claude Nicollier has been named by NASA as a crew member for STS-61, the Shuttle mission that will service the Hubble Space Telescope (HST) towards the end of 1993. In his role of Mission Specialist, Nicollier will also have the task of operating the Shuttle's Remote Manipulator System (RMS) during a complex mission that foresees a high amount of Extra Vehicular Activities.

Nicollier's first shuttle flight took place on 31 July 1992 on the STS-46 mission that successfully put into orbit Eureca, the first European retrievable carrier. A detailed report of the STS-46 mission appears on p.23 of this issue.

During the HST servicing mission to which Claude Nicollier has just been assigned, the two solar arrays will be replaced and the corrective optical device will be installed to recover full capability of the orbiting telescope. Launched on 24 April 1990, the HST is an international cooperative mission between ESA and NASA. ESA contributed the two solar arrays and the Faint Object Camera to this unique mission that has so far provided unprecedented results.

Jean-Marie Luton, Director General of ESA, acknowledged with pleasure the NASA announcement and said, "this is once more an example of good cooperation between NASA and ESA showing the will to continue towards real multi-organisational achievements in space activities".

Claude Nicollier added "This is a great mission and I am very happy about this assignment. I will be acting as Mission Specialist 2 with responsibilities as flight engineer for the ascent and re-entry phases, rendezvous support, shuttle systems management on orbit and RMS operator".

Claude Nicollier is a Fellow of the British Interplanetary Society.

Russian Launches Down

Yuri Koptev, the head of the Russian Space Agency has reported that space launches have fallen behind schedule in the country.

He revealed that, to November 10, only 14 out of 25 planned civilian launches had taken place and out of 70 planned military launches there had been just 27.

Koptev said that Russia's space programme and infrastructure was on the brink of crisis. Professional staff were being lost to other jobs raising the possibility that the space programme might not survive.

Russia had 102 satellites in orbit, Koptev said (presumably operational) with 35% of those being civilian in nature.

Vladimir Postyshev, described as a "chief expert" of the Russian parliament's commission for transport, communications, information and space research said that the annual losses suffered by Russia due to the "uncontrollable export of space know-how" were amounting to some one billion dollars.

Over the past 8 months less than 50% of the budget allocated to them in 1992 had been received by the more than one thousand space research centres. Because specialists in these facilities receive about half of the earnings of other researchers there had been a loss of some 30% of the available specialists in the field.

Postyshev said that the Republic of Kazakhstan was bearing just 6% of the cost burden for the Tyuratam cosmodrome - the balance being borne by the Russian Federation.

Neville Kidger

Buran's Remote Manipulator Arm

A remote manipulator arm is being developed for the Russian Buran shuttle orbiter at the Central Scientific Research Institute of Robot Technology and Technical Cybernetics located in St Petersberg, Russia.

The arm, designed for the placement and retrieval of payloads in space is 15.3 metres long with a mass of 350 kg. The arm is reportedly capable of placing 30 tonnes into orbit from the cargo bay of the Buran shuttle orbiter and has a speed of movement of 4 centimetres per second.

The arm is designed to be operated automatically but it can also be controlled manually, according to the designers.

Neville Kidger

Launch of NAVSTAR (GPS) Satellite

The US Air Force launch of a NAVSTAR Global Positioning System (GPS) satellite from Cape Canaveral Air Force Station, Florida on 22 November 1992 was the 10th successful launch this year of a McDonnell Douglas-built Delta expendable launch vehicle. Over the past 15 years and 82 launches, Delta rockets have maintained a 98.8 percent success record.

The GPS is a space-based radio navigation system that provides US and allied land, sea and air forces with worldwide, three-dimensional position and velocity information. It was boosted by a 7925 configuration of the Delta II into its transfer orbit.

CHINA

To Participate in MARS-96...

Chinese scientists are to cooperate with Russian colleagues during he MARS-96 unmanned exploration mission, the Chinese news agency Xinhua reported recently.

Chinese and Russian scientists have, for the past two years, cooperated with each other in research using high altitude sounding balloons for the detection of cosmic radiation. Several of these balloons have been launched from China and have landed in Russia.

Balloon technology, according to the Russian Academy of Sciences President Yuri S. Osipov, will be a main feature in the MARS-96 project.

The probe will be launched in 1996 and part of it will attempt to land on the red planet, releasing balloons as it descends. The balloons are being developed by French, Russian and American scientists.

Neville Kidger

... And Launch Own Manned Shuttle

Construction has begun of a launch site and supply lines for a Chinese space shuttle, a Chinese news agency from Hong Kong reports.

A space centre is being constructed some 200 km from Jiuquan city in Gansu province, and a rail line of that length is being laid. The completion of the first phase of the project is slated for late in this decade.

The unnamed head of the project was reported as saying that the launch and recovery of the shuttle vehicle would be completed from the base and its vicinity. The project was expected to take about 10 years to accomplish although scant details were given in the report.

Neville Kidger

New Space Shuttle Cockpit

Honeywell's Satellite Systems Operation is to build the space shuttle Multifunction Electronic Display Subsystem which will replace/update the fleet's 15-year-old cockpits.

The improved cockpit will incorporate many new features to enhance optimum pilot viewing, convenience and control. It will include flat-panel displays for wide viewing angles, cross cockpit viewing, and high resolution and contrast ratio. Additional NASA hardware and software programs can be added without affecting any of the existing programs.

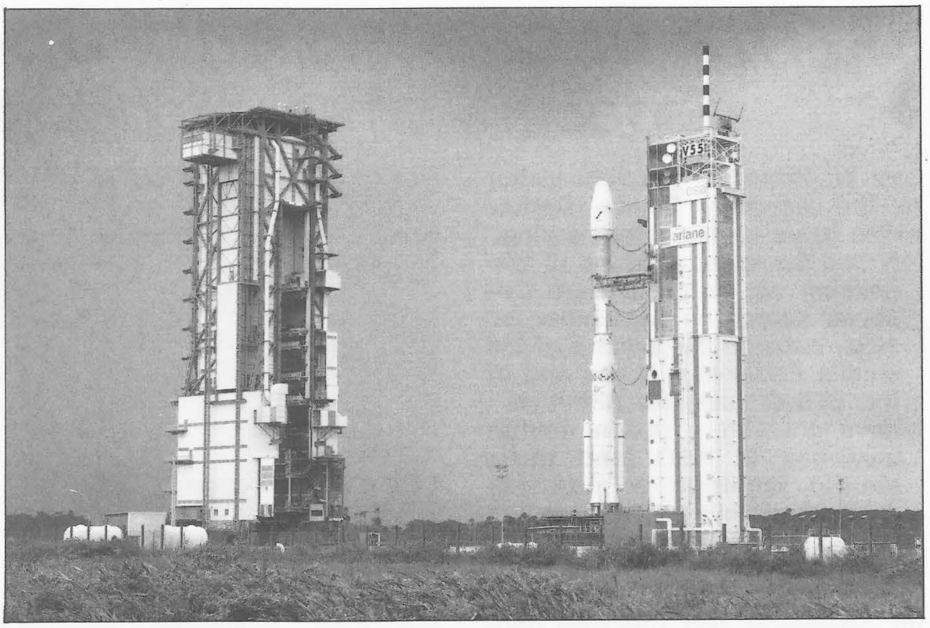
The new design of Display Subsystem will also have a lower cockpit power consumption.

Arianespace V55

Ariane rocket 42P, with two solid strap-on boosters, placed the Superbird-A Satellite in orbit for the Space Communications Corporation of Japan on 1 December 1992 at 10:48 GMT. The new satellite, which has joined Superbird-B launched on 26 February 1992, now assures a continuity of services for Japanese domestic telecommunications.

The dimensions of the main body of Superbird-A are 2.4 x 2.2 m. Its mass at lift off was 2780 kg. Provisional parameters are 199 km perigee, 35,990 apogee and an orbital inclination of 6.99 degrees. The lifetime is expected to be ten years though fuel is present to last 14 years.

Solar array deployment took place about two and a half hours after lift off from Kourou. Superbird-A is to be positioned in geostationary orbit at 150 East Longitude over the Pacific Ocean to provide coverage of the whole of the Japanese archipelago.



Arianespace Flight 55 - Superbird A: the Ariane 42P launch vehicle (2 solid strap-on boosters) in preparation on its pad before launch at Kourou, French Guiana, December 1, 1992. *Arianespace*

SATELLITE DIGEST-248

Satellite Digest is our regular listing of world space launches. Orbital data has been reproduced from the RAE Table of Earth Satellites, produced by the Aerospace Division of the Defense Research Agency.

Name and International Designation	Notes	Launch Date	Launch Vehicle	Perigee (km)	Apogee (km)	Period (min.)	Inclin. (deg.)
NAVSTAR 2A-06, 1992-58A		9.37 Sept 1992	Delta 2	19980	20630	722.94	54.79
KOSMOS 2209, 1992-59A		10.75 Sept 1992	Proton	35764	35806	1435.90	1.32
HISPASAT 1A, 1992-60A		10.96 Sept 1992	Ariane 4	35783	35800	1436.24	0.03
SATCOM C3, 1992-60B		10.96 Sept 1992	Ariane 4	35773	35790	1435.73	0.12
STS-47, 1992-61A		12.60 Sept 1992	Endeavour	299	310	90.58	57.00
KOSMOS 2210, 1992-62A		22.67 Sept 1992	Soyuz	175	349	89.76	67.16
FREJA, 1992-64A	(1)	6.26 Oct 1992	CZ-2C	596	1762	108.97	63.01
CHINA 38, 1992-64B	(2)			215	311	89.76	63.01
FOTON 5, 1992-65A	(3)	8.79 Oct 1992	Soyuz	220	359	90.31	62.81
DFS 3, 1992-66A	(4)	12.41 Oct 1992	Delta 2	35778	35797	1436.04	0.05
MOLNIYA 3-42, 1992-67A		14.83 Oct 1992	Molniya	477	39877	717.75	62.84
KOSMOS 2211, 1992-68A		20.54 Oct 1992	Tsiklon	1400	1415	114.00	82.59
KOSMOS 2212, 1992-68B				1408	1414	114.09	82.59
KOSMOS 2213, 1992-68C				1409	1418	114.14	82.59
KOSMOS 2214, 1992-68D				1414	1422	114.23	82.59
KOSMOS 2215, 1992-68E				1413	1428	114.29	82.60
KOSMOS 2216, 1992-68F				1410	1417	114.14	82.60
KOSMOS 2217, 1992-69A		21.43 Oct 1992	Molniya	599	39757	717.79	62.95
STS-52, 1992-70A	(5)	22.72 Oct 1992	Columbia	206	215	88.51	28.47
LAGEOS 2, 1992-70B	(6)			5617	5950	222.42	52.64
CTA, 1992-70C	(7)			208	215	88.53	28.46
PROGRESS-M 15, 1992-71A	(8)	27.72 Oct 1992	Soyuz	269	323	90.38	51.62
GALAXY 7, 1992-72A		28.01 Oct 1992	Ariane 4	199	29834	518.52	6.95
KOSMOS 2218, 1992-73A		29.45 Oct 1992	Cosmos	968	1015	105.00	82.92
EKRAN 20, 1992-74A		30.63 Oct 1992	Proton	35575	35692	1428.19	1.58

NOTES

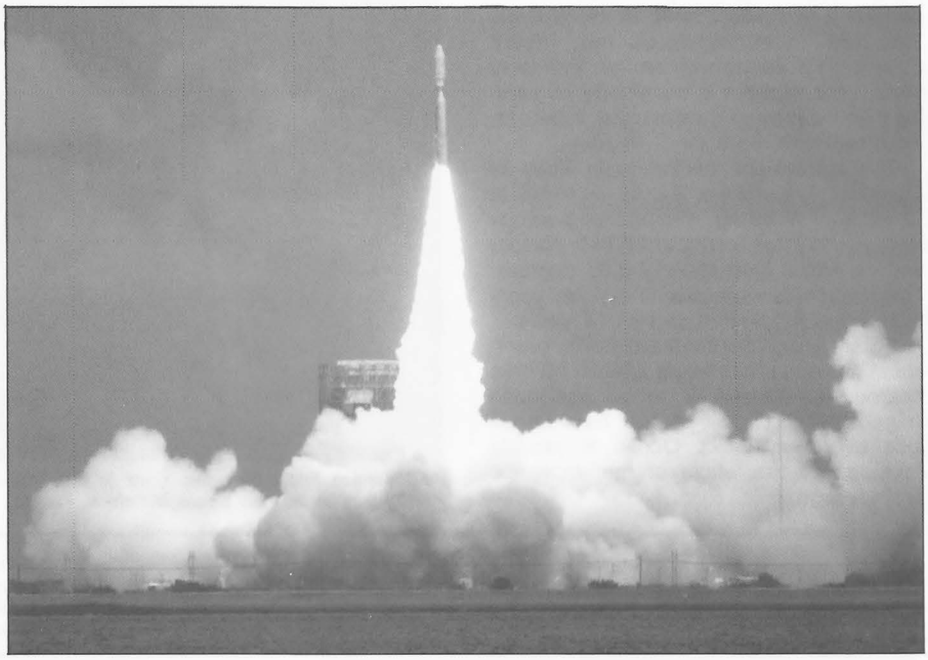
(1) Swedish auroral and magnetospheric satellite
(2) Transmitted until 1992 October 21. Capsule returned to SW Sichuan Province on 1992 October 13.19.
(3) Microgravity materials processing. Carried the German payload, Biopan, a pan with a lid mounted on the outer surface of the capsule to allow biological effects in the space environment. Launch was from Plesetsk.
(4) Multi-purpose communications satellite for Deutsche Bundespost Telekom.
(5) Launch and landing at Cape Canaveral (1 woman, 5 men including a Canadian payload specialist). Cargo bay carried US Microgravity Payload, USMP-1 (not separated) and Canadian experiments, CANEX-2, extensions of CANEX on STS-41G.
(6) Built by Agenzia Spaziale Italiana (ASI) using drawings and specifications for Lageos 1. Ejected from Shuttle on 1992 October 23.58.
(7) Canadian Target Assembly ejected from Shuttle on 1992 October 31.42.
(8) Progress-M 15 docked with Kvant 1 (-X prot) on 1992 October 29.80.

The Excitement of Space Flight
(Especially While Attending in Person!)

Joel W. Powell, a frequent visitor to the Kennedy Space Center writes to us on his return saying,

"I had the great privilege of witnessing not only the Mars Observer launch on September 25, 1992, but also the landing of the shuttle Endeavour at the end of the STS-47 mission. Although I have covered a dozen shuttle launches at KSC (and three shuttle landings at Edwards AFB) I had never seen a landing or a Titan ELV launch at the Cape."

Joel writes about his experience for *Spaceflight* and provides photos* that he took of each of these two events.



Mars Observer liftoff from pad 40 at the Kennedy Space Center on a Titan 3 rocket, Septermber 25, 1992.

Joel W. Powell

STS-47 Landing

The landing itself was the most exciting space event I have ever seen due to the closeness of the viewing area to the runway (only a couple of hundred yards from the position when the drag parachute was deployed). Television does not do the event justice.

After the final descent and touchdown at the far end of the runway, the orbiter rolls down the runway and streaks into view in front of the viewing area, simultaneously popping out the drag chute while still travelling at a high percentage of its 200+ mph touchdown speed. It was electrifying, all the more so because this great flying machine had just returned from outer space.

For this observer at least, the passage of nearly a dozen years of shuttle flights has not yet diminished the excitement of space flight (especially while attending in person!). We spotted the orbiter high overhead shortly after the twin sonic booms rang out, and the orbiter (which was in the process of a steep right bank) was clearly identifiable as the space shuttle without the need of an optical aid.

Endeavour after touchdown at Kennedy Space Center, September 20, 1992. *Joel W. Powell*

This landing was only the 12th to occur at KSC in 50 shuttle flights. Most future shuttle flights are now scheduled to land at KSC.

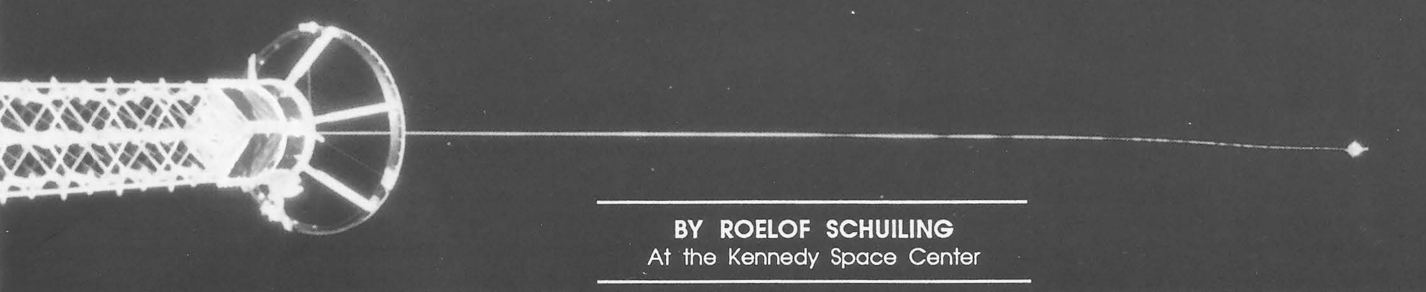
Mars Observer Launch

The Mars Observer launch differed from that of a space shuttle in that the Titan 3 vehicle on the pad presented itself edge-on to the view site with no hint of the central core flanked by the two solid rocket motor configuration. The Titan remained side-on even after heading downrange shortly after liftoff. The vehicle disappeared on one occasion into the overcast but was fully visible from the ground during SRM separation.

The ascent sounded very similar to the shuttle, only not as loud and the crackling sound of the solid propellant motors was not as pronounced. There was a period of great uncertainty when telemetry from the TOS stage was not received, and a great feeling of relief when contact was finally established with the Mars-bound spacecraft. The seventeen year wait between Mars launches indeed ended in dramatic fashion.

* Both photos were shot on ISO 100 film using a 500 mm lens from the press area provided by NASA for these events, that is the Shuttle Landing Facility for the landing and the NASA Causeway located on the KSC Industrial Area for the Mars Observer launch.

Snags Hit Tethered Satellite Mission



BY ROELOF SCHUILING
At the Kennedy Space Center

The Tethered Satellite System (TSS) approaches 800 feet from its boom, located in the cargo bay of the Earth-orbiting Space Shuttle Atlantis. The Moon can be seen at upper right centre. A crew of seven spent eight days in space supporting the TSS operations and other experiments. *NASA*

The Space Shuttle Atlantis was launched on mission STS-46, Atlantis's 12th and the programme's 49th flight, at 9:57 EDT, on July 31, 1992. The launch from the Kennedy Space Center's (KSC) Launch Complex 39B came only one minute later than planned as a momentary hold at T-5 minutes was called to ensure that one of the many steps in the countdown had been verified.

Processing for STS-46 began at KSC with the landing of Atlantis following STS-45. Atlantis was moved into the Orbiter Processing Facility (OPF) work bay 1 on April 3.

Atlantis spent a period of 63 days in the processing facility. While there, Atlantis had the previous payload, the ATLAS-1 Spacelab, removed from its payload bay and the orbiter was reconfigured to support the payloads for STS-46. In addition, since ATLAS-1 had not required the Remote Manipulator System's robot arm, this was installed in the payload bay for use on the upcoming mission.

An additional task in the processing facility was the removal of the main engines which had been used on STS-45 and the installation of the engines for STS-46. Engine 2024 was installed in the number 1, or upper, position; engine 2012 in the number 2, lower left, position; and engine 2028 in the number 3, lower right, position.

During the period when the Atlantis was in the OPF an IMAX camera was installed in the payload bay and tested. The IMAX camera would provide large format photo coverage of payload operations on-orbit.

The payload bay interior was cleaned, the doors closed and on June 4, Atlantis was transported to the Vehicle Assembly Building. On the following day it was hoisted, rotated to a vertical position and mated to the External Tank and Solid Rocket Boosters. Following interface tests to verify connections between the orbiter, External Tank and the Mobile Launch Platform, the Shuttle and its launcher were rolled out to Launch Complex 39B on June 11. Shuttle to pad interfaces were checked and a simulated countdown was run on June 15 and 16 with the flight crew aboard for the final phase. This was followed by the loading of the hypergolic propellants which was completed on the 22nd. STS-46 tests and preparations for payload operations resumed after the launch of its sister ship, Columbia, on June 25.

While plans and preparations for the Atlantis launch were going on, the payload complement for the mission was also preparing for launch. The Tethered Satellite System (TSS) arrived at the Kennedy Space Center's Operations and Checkout (O&C) building in November 1990. During the next year the reel assembly was mounted to the pallet, the satellite support assembly mounted to the pallet, the tether installed and testing and verification was accomplished. Beginning in December 1991, the satellite was mated to the satellite support assembly, the tether to satellite connections and attachments to the deployer boom were accomplished. Functional, interface and mission sequence tests were run in February and March. In April the TSS was moved to a test stand which simulated the orbiter's systems: the payload's orbiter interfaces and network data communications were verified there. Closeout operations, thermal blanket installation and Astronaut inspections took place in the May-June time frame. Also, during this period it was determined that the conductive paint that covered the skin panels of the satellite might lose its conductive features in space. This was a major concern as much of the TSS data dealt with electrodynamics factors and it was decided to replace the painted skin panels using a more suitable paint. This was completed in early June.

Also undergoing integration and tests in the O&C building was the EOIM/TEMP payload. EOIM, or Evaluation of Oxygen Interaction with Materials, and TEMP, or Two Phase Mounting Plate Experiment, were mounted on a trusswork structure following their arrival at KSC in December 1991. The EOIM/TEMP was also transferred to the orbiter simulator test stand and interfaces with the simulated orbiter were checked in April.

The TSS and the EOIM/TEMP were installed in the payload transfer canister on June 25 for transport to the launch pad.

Before moving out to the pad, however, the canister and payloads had to make a short detour to pick up the Eureca deployable satellite. The Eureca, or European Retrievable Carrier, had arrived for processing in November 1991. It was integrated and tested at a commercial payload processing facility adjacent to KSC. The testing was completed in May 1992 and Eureca was moved to the KSC's Vertical Processing Facility (VPF). Eureca to orbiter connections were simulated and verified in the VPF. Eureca was installed into the transfer canister on July 2. The major payloads were now ready to move out to the launch pad where they were installed into the Shuttle's rotating service structure on July 6.

On July 8, the service structure was rotated alongside the Atlantis' payload bay, the payload bay doors opened and the payloads were installed.

A series of interface verification tests between the orbiter and the payload complement followed the installation. The Eureca interfaces with the RMS and with the orbiter systems were verified on July 9 and 10. The TSS interfaces with Atlantis were checked out July 11 and the EOIM/TEMP interface test was the 13th. As a problem was found with an environmental monitor electronics unit on the EOIM/TEMP payload, the unit was removed, repaired and successfully rein-

Claude Nicollier, representing the European Space Agency (ESA) onboard Atlantis for the STS-46 mission, is seen on the flight deck during pre-deployment operations with the ESA's Eureca satellite. Eureca can be seen on the end of the remote manipulator system (RMS). *NASA*

stalled a week later.

On June 10, the Flight Readiness Review was held and mission managers confirmed July 31 at 9:56 am for the launch. Earlier planning had envisioned a mid-July launch date but Eastern Test Range scheduling concerns, including the time-sensitive launch of the Geotail satellite aboard a Delta rocket, contributed to the change.

Following the payload interface tests the first orbiter ordnance operations took place on July 14. The next several days saw closeout work continuing in the engine compartment, closeout and inspections of the SRB holddown posts, inspections of heat shields and the replacement of the pilot's video display CRT in the flight deck. Over the weekend of the 18-19 only minimal work was done and launch crews had a chance to take some time off.

On the 20th, the replacement CRT was tested, Shuttle closeouts continued and two space suits were installed in the Atlantis' airlock in case a contingency EVA was required. Crew stowage and closeouts took up the next several days and on the 24th final ordnance operations were completed. An auxiliary power unit heater thermostat was replaced the following day in addition to normal closeout operations. TSS batteries were installed and the Atlantis' hypergolic pressurisation system was pressurised for flight.

Launch countdown preparations were begun with the countdown set to start at 4:00 pm on the 28th. Final payload closeouts and inspections were made. During the course of the inspections six connectors were noticed to have backshells which were loose. These were repaired and the payload bay doors were closed for flight on the 29th. Also on the 29th, the first built-in-hold of the countdown occurred from 8:00 am to 12:00 noon at the T-27 hour point. Later on the 29th, loading of the liquid hydrogen and oxygen cryogenic reactants for the orbiter's fuel cells was accomplished. A second built-in-hold at the T-19 hour point lasted from 8:00 pm to midnight.

On the 30th, the T-19 to T-11 hour segment of the count included communications systems activation, removal of throat plugs and covers from the manoeuvring engines, main engine checks and purges, tail service mast closeouts and cabin configuration activities. An 11 hour 36 minute built-in hold began at 8:00 am on the 30th during which the inertial measurement units activation and warm-up began. On the afternoon of the 30th the service structure was rotated clear of the Shuttle and final safety and fire department walkdown inspections of the launch pad were made. Inside Atlantis' cabin final stowage and ascent switch configurations were done.

After picking up the count as planned at 7:36 pm, the pad was cleared and fuel cell activation was accomplished. Preparations were also underway for the loading of the External Tank. A one hour built-in-hold at T-6 hours, 12:36 am, on the 31st saw the Launch Danger Area cleared. Loading of the External Tank began at T-6 hours at 1:36 am on the 31st and continued through T-3 hours. Inertial measurement units' pre-flight calibration was also done in this period. A two-hour built-in hold at the T-3 point allowed the ice/frost team to inspect the External Tank following its loading. Inside the cabin a final inspection was made and communications systems configured for launch. In their quarters in the O&C building the flight crew were awakened and began their preparations.

Shortly after the count resumed, the flight crew departed for the pad and from approximately T-2:25 to T-1:20 they completed equipment checks, entered Atlantis and the hatch was closed and secured. Final countdown operations and weather briefings were completed. At T-20 minutes a 10 minute built-in hold was held during which the NASA Test Director gave a final briefing to the launch crews.

The last built-in hold occurred at T-9 minutes from 9:37 to 9:47 am. Following this, the crew access arm was retracted and preparations for starting the auxiliary power units were done. A one minute hold at T-5 minutes allowed a final verification to be made and the units were started at T-5 and counting.

The auxiliary units' starting sequence was completed and checks verified the operation of the flight control surfaces, speed brake and body flap. The gimballing of the main engines was checked as the orbiter's engines were cycled through a planned sequence of moves to verify their pointing systems. The electric power was switched from ground to onboard electrical power.

External Tank pressurisation was initiated and the oxygen vent hood retracted. About two minutes before flight the last direction to the crew from KSC was given: "Close and lock visors". Liquid hydrogen vent valve closure and the liquid hydrogen pressurisation began.

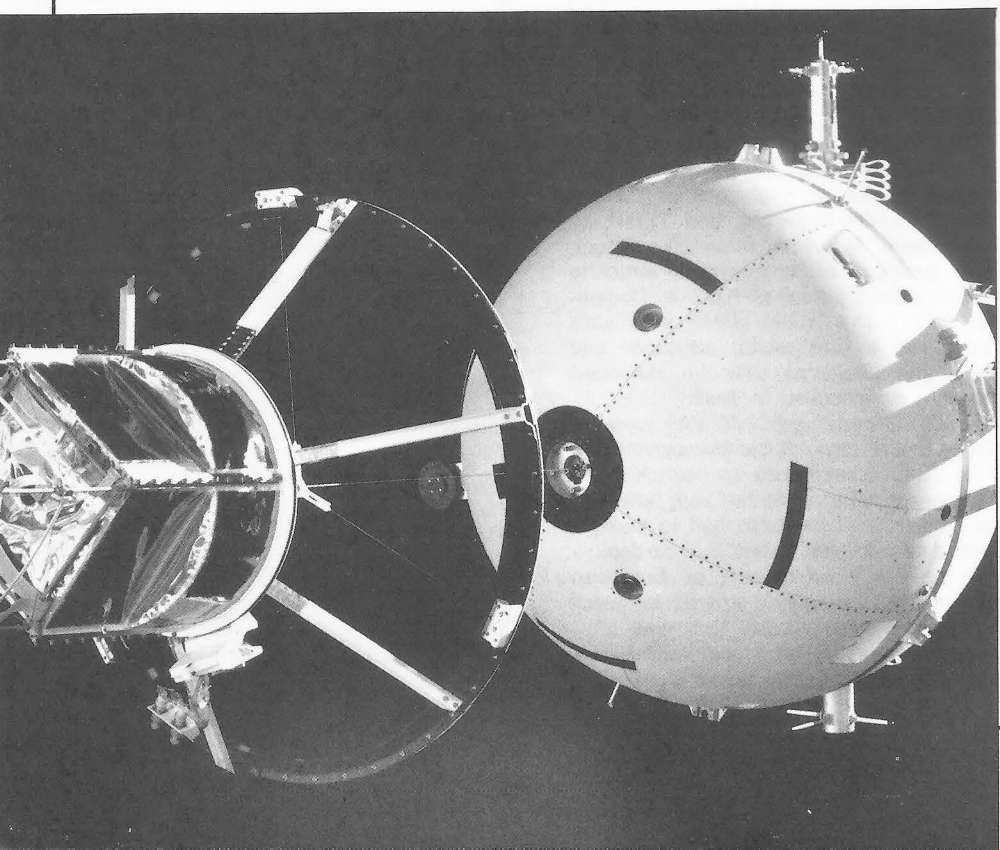
Solid Rocket Booster heaters deactivated at T-1 minute. Outboard liquid hydrogen and oxygen fill and drain valves closed and at T-31 seconds the Launch Processing System gave a "go for auto sequence start".

Operating under the computerised sequence, the SRB gimbals were checked and the launch pad sound suppression water system activated.

At T-10 seconds the hydrogen burn system ignited to burn off any free hydrogen in the area of the engines and the Ground Launch System gave a "go for main engine start". Shortly after T-7 seconds main engine 3 started followed by 2 and 1. By T-6 seconds all main engines were up and running. At T-0 the Solid Rocket boosters ignited and at 9:57 am Atlantis began mission STS-46.

As Atlantis arced into the hot Florida sky it performed a rolling manoeuvre from T+10 to T+15 seconds to bring it to its correct attitude. Twenty-six seconds into the mission the main engines throttled back to 80 percent and at T+53 seconds they were throttled back to 67 percent thrust to allow safe passage through the maximum dynamic air pressure (Max Q) at T+1 minute 4 seconds. The engines were throttled up to 104 percent, the Solid Rocket Boosters separated at 2 minutes 4 seconds into the mission and main engine cutoff came at 8 minutes 29 seconds. External Tank separation came 6 seconds later and the Orbital Manoeuvring System burn occurred at T+41 minutes 24 seconds.

A 70 mm handheld camera was used by the STS-46 crewmembers to capture this medium closeup view of early operations with the Tethered Satellite System (TSS). The sphere can be seen moving away from the ring structure on the boom device in Atlantis' cargo bay. *NASA*



Day One: July 31, 1992

Following its insertion into a 230 nautical mile orbit - chosen to allow the Eureca satellite to be deployed above potentially hazardous drag from the residual atmosphere - Atlantis went through standard post insertion operations and was readied for orbital operations. The payload

The seven cewmembers for the STS-46 mission pose for the traditional inflight portrait onboard the Earth-orbiting Atlantis. In the rear are, left to right, astronauts Loren J. Shriver, mission commander; Andrew M. Allen, pilot; and Franklin R. Chang-Diaz, mission specialist. In front are, left to right, Swiss scientist Claude Nicollier, representing the European Space Agency as mission specialist; astronaut Jeffrey A. Hoffman, payload commander; astronaut Marsha S. Ivins, mission specialist; and payload specialist Franco Malerba, representing the Italian Space Agency (ASI). *NASA*

bay doors were opened 90 minutes into the flight and the Ku-band communications/radar antenna was extended about an hour later.

The flight crew was divided into two teams termed the "red" and the "blue" teams. The blue team was made up of pilot Andrew Allen, mission specialist Claude Nicollier and payload specialist Franco Malerba. The red team consisted of payload commander Jeff Hoffman, mission specialist Marsha Ivins and mission specialist Franklin Chang-Diaz. The teams worked shifts to provide 24-hour coverage. Mission commander Loren Shriver followed his own schedule. Approximately three hours into the mission, the blue team began their first sleep period and the red team began experiment operations.

The STS-46 mission carried an experiment in its middeck area designed to study pituitary cell growth functions. This was activated on the first day of flight.

Powering up experiments in the payload bay occupied much of the red team's first shift. The EOIM was powered up and activated although actual data operations would be done later in the flight at a lower altitude. The IMAX camera in the payload bay was powered on and the TSS activated and its deployer checked out. The Atlantis' Remote Manipulator System robot arm was checked out in preparation for the Eureca deployment which was set for the morning of August 1, or about three-quarters of the way through the first flight day. The first flight day had begun at 9:57 am Friday and would run through 9:57 am Saturday.

Following the awakening of the blue team, the red team handed operations over to them at about 11 hours into the mission. The red team began their first sleep period in space shortly thereafter. The blue team began preparations for the deployment of Eureca.

However, the deployment was postponed as European Space Agency flight controllers at Darmstadt, Germany noted serious data dropouts in the communications stream coming from Eureca. It became clear that it would not be possible to deploy the Eureca until the problem had been solved and, consequently, the deployment was postponed at least twenty-four hours.

Day Two: August 1, 1992

Eureca controllers at Darmstadt and Shuttle flight controllers at the Johnson Space Center worked together to analyse the situation. The data stream passed through the Shuttle avionics before being sent to the ground and initial investigations centred on that path. However, a direct data path was established from Eureca to Darmstadt *via* the ESA stations at Kourou and elsewhere. This showed that the problem lay within Eureca's data path itself. After evaluating the data stream on a number of passes, Eureca flight controllers deemed the satellite ready for deployment.

Eureca was finally released by mission specialist Claude Nicollier early on the morning of August 2, approximately one day and 19 hours into the mission. Following the deployment of Eureca, its thrusters were ignited to move the satellite away from Atlantis. However, the planned 24-minute burn was aborted and the thrusters were shut down six minutes into the burn. Ground controllers at Darmstadt indicated that data showed Eureca in an incorrect attitude. Although flight crewmen aboard STS-46 could not verify the reported 30-degree attitude error, the decision was made to hold-off on continuing the operation until analysis could determine the condition of Eureca.

The delay in the Eureca operations also caused a delay in the Tethered Satellite operations which had been set to begin on August 3. They would now begin on August 4. Preparations were begun and continued throughout Flight Day Two, Three and into Flight Day Four, that would ready the Tether Satellite System for its deployment and operations.

Day Three: August 2, 1992

Several of the TSS experiments were activated and tested by the red team with no major problems. These included the Shuttle Electrodynamic Tether System (SETS), an experiment that would gauge the amount of electricity being produced and conducted in the tether from the satellite; the Shuttle Electric Potential and Return Experiment, or SPREE, which measures the electron environment around Atlantis prior to and during tether operations; and the Deployer Core Experiment, or DCORE; which regulates the amount of current flowing down the tether and measures the electricity.

Meanwhile, ESA decided to wait until August 4 to continue Eureca boost operations. Attention at this point centred on a possible ground computer problem.

The blue team had a fairly relaxed shift with payload specialist Malerba continuing to monitor the TSS systems and equipment while mission specialists Nicollier and pilot Allen monitored a water dump test using a lower pressure operation.

At approximately 7:00 am on August 3, Atlantis was lowered from 230 to 160 nautical miles altitude. The higher orbit had been used to support the Eureca operations. About 45 minutes later, the

orbit was then circularised, at the lower altitude, to support tether and EOIM operations later in the mission.

Day Four: August 3, 1992

Preparations for the TSS activities continued. The crew of Atlantis continued activation of TSS experiments and a survey of the payload bay was made by instruments in order to characterise the electrical environment within Atlantis' payload bay. Several electron beam firings were performed as part of the characterisation of the electrical environment.

Italian payload specialist Franco Malerba took time out to wish his son happy birthday in French, Spanish, Italian and English, four of the languages which can be spoken by the Atlantis' crew.

Eureca ground controllers continued to analyse the data from their satellite and determined to postpone continuation of the thruster firing for several days to allow further analysis.

Day Five: August 4, 1992

Shortly before noon (EDT) on August 4, the red team of crewmembers began to extend the TSS boom. The collapsible boom, designed to move the satellite far enough away from the Shuttle so as to pose no danger during deployment, was extended to about 40 feet above the payload bay. At this point two umbilicals were to be released by the crew's command, thereby freeing the tethered satellite from the boom so that it could begin its journey away from Atlantis. Although umbilical number one disengaged satisfactorily, umbilical number two would not come loose.

Eight attempts to disengage the recalcitrant unit failed, however: after firing one of Atlantis' attitude jets while sending the disengage command the crew was successful and the satellite was free of the boom. The delays had taken two orbits to resolve and the experiment operations were now behind schedule. Because of the delay flight planners decided to extend the satellite only six miles rather than the planned 12 miles to get the experiment back on its timeline.

As the red team attempted to send the satellite out on the end of its tether, the tether mechanism suffered successive jams. After the second jam halted satellite operations the TSS satellite was at a distance of 860 feet from Atlantis. At this point the red crew had been awake almost 20 hours throughout August 4. Mission controllers decided to postpone further TSS Operations until the crew had a chance to rest and sleep. The red crew, therefore, went to sleep at about 1:00 am on the morning of Wednesday August 5. Mission managers also decided that the STS-46 mission would be extended one day as the mission was behind the preflight timeline due to the Eureca and TSS problems.

After about seven hours of sleep, the red crew prepared for another attempt to send the tethered satellite further.

Day Six: August 5, 1992

The attempt to extend the satellite further began by reeling the satellite in and then reeling it out at a higher speed than had been used the previous day. Operations were again unsuccessful and the satellite operation jammed again.

As the tether operations were in progress, the orbiter suffered periodic communications drop-outs with the ground due to its flight attitude. With the tethered satellite above it and the payload bay open and facing away from the Earth's surface, the orbiter's antennas were occasionally blocked by its structure. The drop-outs were of short duration and did not affect the mission. The orbiter had to maintain a payload bay up attitude as the tethered satellite was in a stable gravity gradient position above Atlantis' orbital altitude.

As the mission moved into its sixth day attempts to deploy and retrieve the TSS satellite were unsuccessful. The satellite was in a stable attitude but the mechanism was jammed with the satellite 750 feet above Atlantis. At this point mission managers were considering several options. Included in these options was the use of an Extravehicular Activity (EVA) spacewalk to attempt to free the mechanism. By this point it was decided to abandon attempts to extend the tethered satellite to its planned distance and to simply retrieve it. In support of the possible EVA operation mission specialists Hoffman and Chang-Diaz began breathing oxygen through masks and later the cabin was depressurised to 10.2 psi.

The contingency EVA, however, proved unnecessary as the crew was successful in clearing the jammed tether by bringing the extended boom back towards the Shuttle and then extending it. Shortly before six days eight hours mission elapsed time, the TSS satellite began its journey back to the Shuttle. The satellite was docked to the extended boom a little over an hour later. As the satellite moved in towards the Shuttle, mission commander Loren Shriver held the orbiter below it with 0.1 foot-per-second impulses from the orbiter's thruster jets.

Day Seven: August 6, 1992

The focus of the day's activities aboard the Shuttle was the Evaluation of Oxygen Interaction with materials (EOIM) which studied the interaction of atomic oxygen in low Earth orbit with various materials. In preparation for this activity, the orbit of Atlantis was reduced from 160 nautical miles to 124 nautical miles. Crewmembers also worked with the CONCAP-II GAS canister to study heated materials' interaction with the space environment. They also performed low-light level photography of the Shuttle atomic oxygen glow phenomenon in low Earth orbit. Some additional research was done using the experiments on the TSS carrier structure to study the Shuttle payload bay environment.

A call from Jean-Marie Luton, Director General of the European Space Agency and Adolph Ogi, Vice-President of Switzerland, was received aboard Atlantis by mission specialist Claude Nicollier who also answered questions from the European press. Later the entire crew participated in an on-orbit press conference to discuss the progress of the mission.

The Eureca ground controllers reported success in boosting their satellite into its intended orbit after first thoroughly verifying the health of their systems. Eureca was first placed in an interim orbit and then in the final orbit. Eureca is scheduled to be retrieved by Endeavour on mission STS-57 in Spring 1993.

Day Eight: August 7, 1992

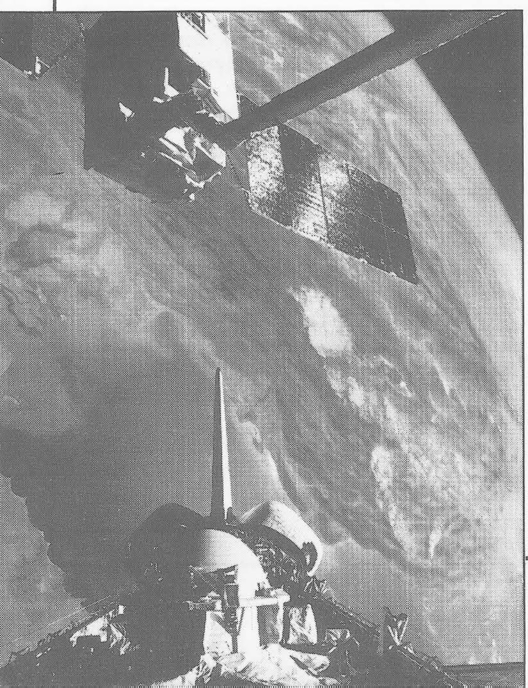
The astronauts aboard Atlantis spent much of the day in preparation for the landing. Commander Loren Shriver and pilot Andy Allen conducted a thorough checkout of their ship's flight control mechanisms and manoeuvring jets prior to their last sleep period.

The red team awakened at approximately 1:00 am EDT for the planned 7:38 am landing at the Kennedy Space Center. The weather at the Florida site, however, proved to be unacceptable for the planned landing time due to rain showers in the area. Mission controllers extended the flight an additional orbit and this time the weather was within operationally acceptable limits. Atlantis touched down on KSC's runway 33 at 9:11:50 am on August 8. Total elapsed time to wheel stop was seven days, 23 hours, 16 minutes and 10 seconds. The total distance flown was 3,321,007 miles during the 127 orbit flight. This was the eleventh time a Shuttle Orbiter had landed at the KSC landing facility.

Atlantis was later towed to the Orbiter Processing Facility for post-flight deservicing and inspections. Atlantis will now undergo an extensive period of modification and refurbishment at Palmdale, California.

The flight crew underwent routine medical checks and then departed for Houston later on August 8.

The European Space Agency's Eureca satellite remains in the grasp of Atlantis' remote manipulator system (RMS) as the Space Shuttle passes over the Persian Gulf. Most of the theatre of the recent war is visible in the frame. Parts of Kuwait, Iraq, Iran and Saudi Arabia can be delineated. The Tethered Satellite System (TSS) remains stowed in the aft cargo bay of Atlantis. *NASA*



Astronauts Lead Earth Watch

This photograph of the New York metropolitan area was obtained in April 1991 during the STS-39 mission using a Hasselblad 70mm camera equipped with a 250mm lens. Almost all the major man-made structures in the area are visible including ship traffic in New York harbour, airports, bridges and urban developments. *NASA*

ASTRONAUTS and cosmonauts alike are very clear about their favourite activity during a space mission - that is watching the varied features of planet Earth pass below them. This visual experience has certainly had a huge impact on the men and women who have orbited our planet and ventured beyond.

BY KEITH T. WILSON

For over thirty years of manned space flight astronauts and cosmonauts have marvelled at the beauty of our planet from space and in the process have taken thousands of photographs. From the time of the first manned missions in the early 1960s it became apparent that these photographs had more than just aesthetic value - much could be learned about our planet from photographs taken from the unique vantage point of Earth orbit.

Human space travellers are not of course the only ones responsible for space-based Earth imagery. A host of unmanned remote sensing spacecraft such as Landsat, Spot, ERS-1 and JERS-1 daily acquire detailed images of our planet. The data such spacecraft return is without doubt immensely useful to the scientists who study the returned images of our planet. However, human-operated photography of Earth features is unique. Humans are able to identify, select and photograph important features of interest; they can obtain photography in a variety of directions with a variety of cameras and lenses; they can take a number of photographs of a particular feature and they can provide real-time oral descriptions of features or phenomena being imaged. Having a trained Earth-observer onboard an orbiting spacecraft is a great advantage.

Over 40,000 images of our planet were obtained by astronauts during the Mercury, Gemini, Apollo, Skylab and Apollo-Soyuz missions. The majority of these were obtained during the long-duration Skylab space station flights in 1973-74. These photographs documented geological, meteorological, oceanographic and environmental phenomena around the globe.

Space Shuttle Missions

Today the Space Shuttle programme continues the process of acquiring hand-

held Earth photography. Approximately eighty five percent of photography on any single Shuttle mission is Earth views. Since Columbia rocketed into space on the STS-1 mission in April 1981 US astronauts have been responsible for taking over 100,000 photographs of our planet. The acquisition of such a vast amount of imagery does of course require meticulous planning and support. It was for this reason that the Space Shuttle Earth Observations Project was established at NASA's Johnson Space Center in the early 1980s to support the acquisition of Earth photography through the use of hand-held photography obtained by Shuttle crews.

Shuttle Earth observations are the responsibility of the Flight Science Branch at the Johnson Space Center. FSB's primary responsibility is to train Shuttle crews to collect useful Earth observation photography. Secondary functions include real-time mission support; coordination of requests for Shuttle Earth observations; coordination of data collection from unmanned remote sensing satellites during Shuttle missions and the cataloguing, indexing and analysis of obtained Earth photography from space.

Astronauts undergo an intensive training programme in which they are trained in the scientific observation of a variety of Earth science phenomena. Training begins when a crew is named for a flight, usually about a year prior to launch. Crewmembers attend a series of thirteen lectures on Earth sciences including Geography, Oceanography, Meteorology, Geology, Ecology, Vulcanology, Geomorphology and impact craters. Their training also involves technical briefings on photographic equipment, photography techniques and the characteristics of different types of film. Numerous meetings with operations personnel such as flight directors and flight activity officers also take place.

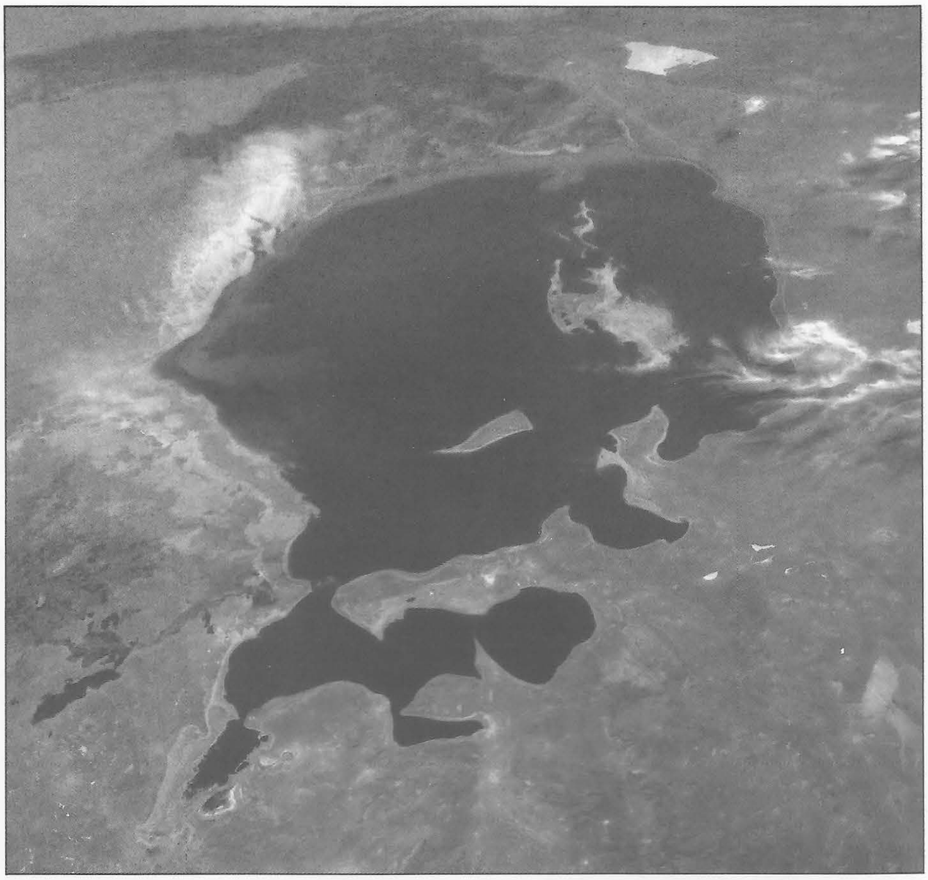
Once the mission flight plan is available, the FSB begin to select specific sites of interest for orbital photography. A lead mission scientist is appointed and is responsible for all the planning, flight activities and post-flight activities. Four NASA and four Lockheed scientists rotate as mission science and operations leads for the Earth observation aspects of Shuttle flights. Requests for specific photographic coverage are also received from scientists around the world.

Image Selection and Cataloguing

Specific Earth observation sites of interest are selected based on the feasibility of acquiring photography; the scientific, public relations and educational merit of the photography over the proposed site; the amount of previous Shuttle photography or other imagery which may be available; the available time of the Shuttle crew and the atmospheric conditions at the time of the proposed acquisition. Sites are selected both several months in advance and also daily during the flight. The majority of Earth photography is unscheduled and is obtained by astronauts during their free time. This does cause some sites of interest to be lost and on flights where the crew work only one shift some sites are missed during crew sleep periods.

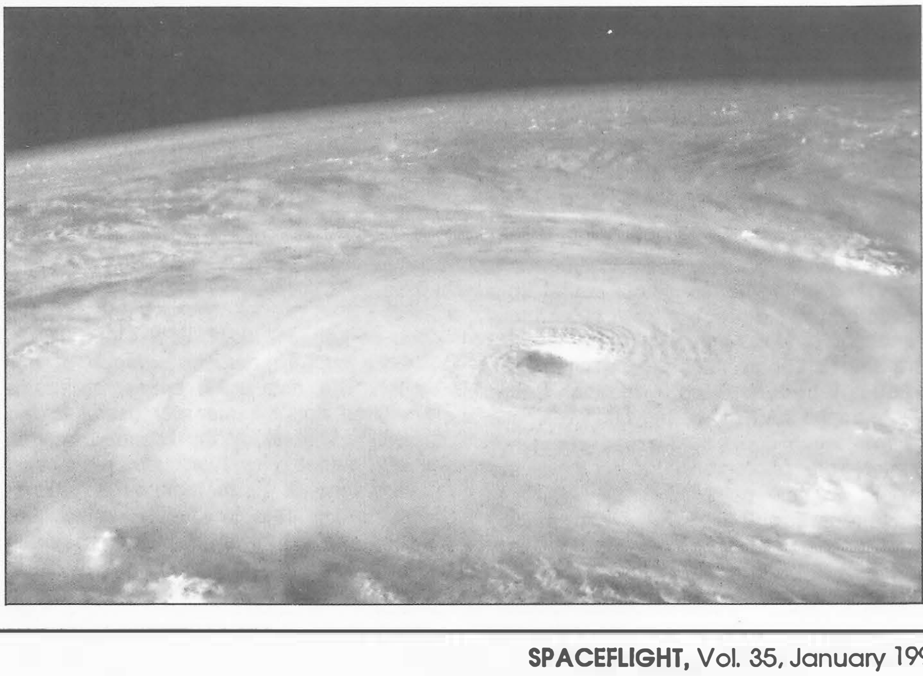
During the Shuttle missions FSB staff are on duty around the clock and keep in close contact with the astronauts, providing them with updates on conditions at selected sites of interest and on environmental conditions around the planet such as oil spills, hurricanes, volcanic eruptions and fires. They also provide initial interpretations of observations made by the astronauts.

Following return of the Shuttle the FSB staff are involved in crew debriefings during which the astronauts are shown imagery which they have obtained. Comments made by crews at this time often add to the scientific value of the photography. It is during these debriefings that



Astronauts aboard the Space Shuttle during the STS 51-F mission photograph the shallow Aral Sea in central Asia. The sea is an internal drainage basin whose only outlet is by evaporation. The flow of rivers entering the sea in recent years has been diverted for irrigation purposes and the result has been a dramatic lowering of the lake level and exposure of evaporates which are being transported by the wind onto neighbouring land. *NASA*

Tropical Cyclone Kamysi in the western Indian Ocean as seen by the STS 41-C crew during their April 1984 mission. When the cyclone hit the port of Majunga in western Madagascar thousands of people were left homeless due to winds in excess of 200 km per hour. The eye of the storm is clearly visible in this oblique photograph. *NASA*



the astronauts select Earth scenes for presentation at the post-mission crew press conference and for additional public appearances.

Within days of the conclusion of a Shuttle mission the FSB staff begin the task of cataloguing, indexing and analysing the returned Earth photography. The photography is indexed both in printed from and on a computer database. A comprehensive mission catalogue is published for each flight listing data on all Earth images for that particular mission. This is usually published some six months after the flight.

Orbits and Equipment

Unlike the Sun-synchronous orbits of remote sensing satellites such as Landsat, the Space Shuttle operates in a wide variety of orbits and Sun angles. Although the majority of missions fly at 28.5 degree inclination several have flown at higher latitudes of 57 degrees and one (STS-36) has reached 62 degrees. A variety of altitudes are flown ranging from 220 km to 700 km. This provides a wide range of perspectives for Earth photography. Photography from the Space Shuttle is acquired mainly through the orbiter's overhead and aft flight deck windows although the forward flight deck windows and side hatch windows are also used. Astronauts have found it useful to work in twos for Earth photography involving specific targets. One crewmember acts as a spotter and looks out for targets while the second crewmember takes charge of the camera system.

This photograph, taken during STS-45, shows pollution around the Siberian city of Troitsk. Troitsk is the smallest group of three industrial cities on the east side of the Ural Mountains, the other being Magnitogorsk and Chelyabinsk. Both the latter cities have made recent headlines as some of the worst polluted cities in the former Soviet Union. Despite being the smaller of the three, Troitsk, for reasons unknown has the largest area of soot-blackened snow. *NASA*

Shuttle Earth Photography By Mission

Mission	Date	Inclination degrees	Number of Photographs
STS-1	April 1981	40	475
STS-2	November 1981	38	842
STS-3	March 1982	38	514
STS-4	June/July 1982	28.4	459
STS-5	November 1982	28.4	833
STS-6	April 1983	28.4	658
STS-7	June 1983	28.4	904
STS-8	Aug/Sept 1983	28.4	2028
STS-9	Nov/Dec 1983	57	2239
STS-41B	February 1984	28.4	1693
STS-41C	April 1984	28.4	1630
STS-41D	Aug/Sept 1984	28.4	1648
STS-41G	October 1984	57	2467
STS-51A	November 1984	28.4	2055
STS-51C	January 1985	28.4	1095
STS-51D	April 1985	28.4	1469
STS-51B	Apr/May 1985	57	2392
STS-51G	June 1985	28.4	1868
STS-51F	Jul/Aug 1985	49.5	1554
STS-51I	Aug/Sept 1985	28.4	1830
STS-51J	October 1985	28.5	1104
STS-61A	Oct/Nov 1985	57	3534
STS-61B	Nov/Dec 1985	28.4	2737
STS-61C	January 1986	28.4	2148
STS-51L	January 1986	-	-
STS-26	Sept/Oct 1988	28.5	1630
STS-27	December 1988	57	1800
STS-29	March 1989	28.4	2042
STS-30	May 1989	28.8	2235
STS-28	August 1989	57	3469
STS-34	October 1989	34.4	1241
STS-33	November 1989	28.4	2094
STS-32	January 1990	28.5	2577
STS-36	Feb/March 1990	62	2729
STS-31	April 1990	28.4	1986
STS-41	October 1990	28.4	2565
STS-38	November 1990	28.5	1865
STS-35	December 1990	28.4	1275
STS-37	April 1991	28.4	4446
STS-39	April/May 1991	57	3544
STS-40	June 1991	39	2767
STS-43	August 1991	28.4	4180

The 28.5 degree inclination missions allow extensive hand-held photography to be obtained of the tropical and temperate regions of our planet. The tropics are one of the least monitored regions on Earth so the Space Shuttle is a highly useful observation platform for the long-term study of this region. Although high inclination flights do not occur as frequently as the 28.5 degree missions they do add significantly to the wealth of Earth photography returned by Shuttle crews. Because of their unique orbital track it is common for high inclination missions to return a much greater number of Earth photographs than is returned on low inclination flights. On recent missions photography has been returned of the Falkland islands, the Antarctic peninsula, Switzerland, icebergs, Moscow, Greenland and the Kamchatka peninsula.

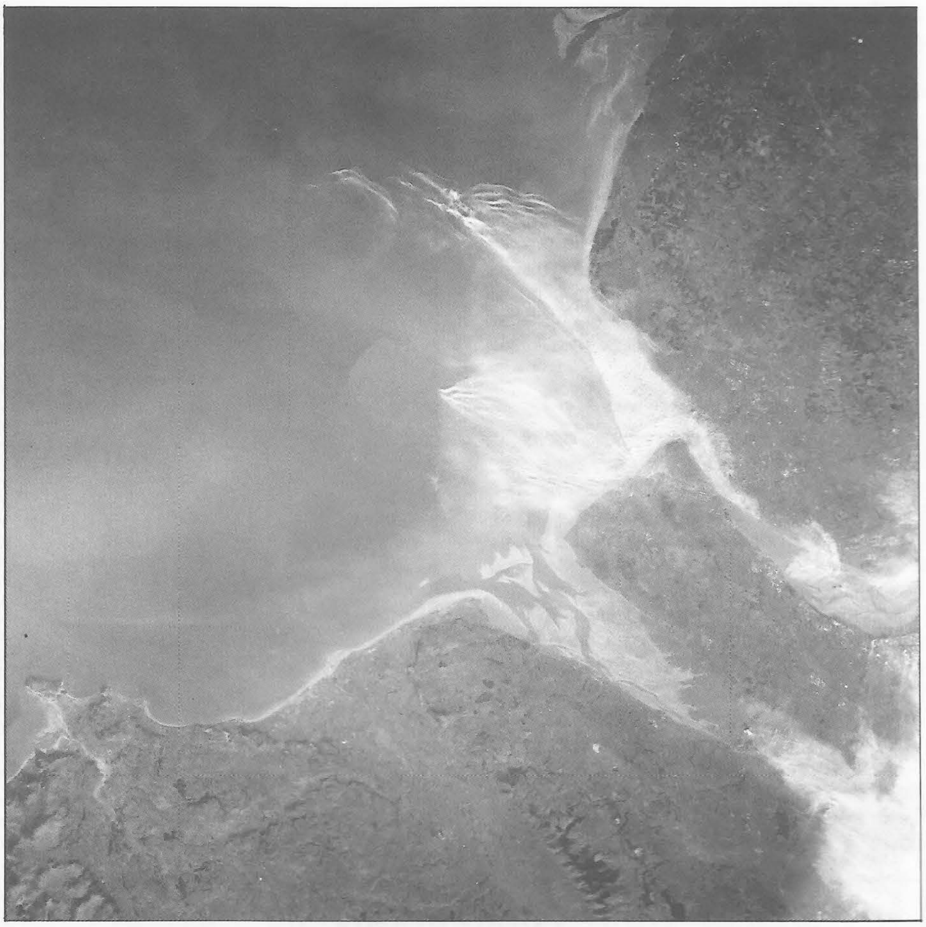
The average Shuttle flight carries approximately 2500-3000 frames of 70 mm film. For longer duration or high inclination missions from 3500-4000 frames of film may be carried. Most of the film carried aboard the orbiter is natural colour although on certain missions colour infrared film is flown. Hasselblad 500 EL/M 70 mm and Aero Linhof Technika 45 handheld cameras are used for the majority of Earth photography. Lenses of 50 mm, 100 mm and 250 mm are used on the Hasselblads and lenses of 90 mm and 250 mm are used on the Aero Linhof. A Rolleiflex 70 mm camera with 50 mm and 250 mm lenses has been utilised for Earth photog-

raphy on recent missions and Nikon F3 and F4 cameras have also captured a few Earth scenes including dramatic auroras on STS-39 and STS-45 using high speed colour film.

As an aid to crewmembers involved in Earth photography the Shuttle Portable Onboard Computer stores information and provides astronauts with Earth photograph target data. In addition, all Earth observation cameras are equipped with data recording modules which automatically record mission data onto the film when it is exposed. When used along with orbital mechanics data recorded during the Shuttle flight it allows scientists to plot the locations of the orbiter. Photointerpretation is used to determine the centre point of each photograph.

A new technology which has recently been introduced to the Shuttle programme and has the potential to greatly improve Earth observation photography is the Electronic Still Camera (ESC). Electronic still photography enables a camera to electronically capture and digitise an image with a resolution close to the quality of film. The image is stored on a hard disk which can be converted and enhanced for transmission to the ground during a flight. The ESC was first evaluated during the 1991 STS-48 mission using a Nikon F4 camera body as the basic photographic platform with CCD array used in place of the film. Crewmembers on this and subsequent missions have used the ESC to successfully image several Earth features of interest.

Having trained observers aboard to quickly identify and photograph new and changing phenomena on our planet makes Shuttle photography a unique resource. Shuttle astronauts and the staff of the Flight Science Branch look set for a busy but highly productive future.



This image of the Liverpool area of England was obtained in January 1992 during the STS-42 mission. The original was shot on colour transparency film loaded in a Hasselblad camera. The area extends from the Great Ormes Head/Llandudno area in the south-west (bottom left) to the mouth of the River Ribble and Lytham St Annes on the coast in the north. The estuaries of the Mersey and Dee are at centre right and in this waveband the sandbanks, sediment flow and wave patterns are much more clearly discernable than the major towns such as Liverpool and Birkenhead. The eastern edge of the mountains of Snowdonia are sharply delineated at the bottom left. *NASA/Space Frontiers*

Sunglint in lower Chesapeake Bay on the USA's east coast was captured on film during STS-40 on June 8, 1991. A Rolleiflex 70mm camera equipped with a 250 mm lens was used to obtain this image. The film was underexposed to reveal the much brighter sunglint features. This has allowed the land/water boundary to be enhanced and clearly shows the intricate structure of the salt marsh tidal creeks along the coast. Also visible is the 13-km-long Chesapeake Bay Bridge at the mouth of the bay as well as several ship wakes. *NASA*

Acknowledgements

The writer would like to thank David Pitts and Becky Fryday of NASA's Johnson Space Center and Al Jean of the EROS Data Center for their valuable assistance during the preparaitron of this article.

The EROS Data Center

Readers interested in obtaining Space Shuttle hand-held photography of particular areas or Earth features should firstly contact the EROS Data Center who will provide them with a computer listing giving data on available photography. The geographic name and latitude/longitude coordinates for the area of interest should be submitted. The EROS Data Center will also provide ordering assistance and price lists.

Contact: EROS Data Center, User Services Section, Sioux Falls, South Dakota, 57198, USA. Telephone (605) 594-6151.

ISU '92

International Space University Kitakyushu, Japan

Where can you have lunch with cosmonauts, learn about the state of the world's Space Industry and make friends with students from 29 countries. Only by attending the ISU summer session is this possible.

***Peter Harris*, a Systems Engineer at British Aeospace Space Systems gives *Spaceflight* his personal impressions of the time that he spent at ISU 92.**

On the eve of 16th June myself and four other British entrants (David Warrell, Justin Paines, Iain Green and Ralph Lorenz) arrived for the 5th ISU summer session in Kitakyushu, Japan. We had all been selected to represent Britain based on our past experience and general enthusiasm for Space.

This was the first ISU to be held in Asia and my first time outside Europe, so armed with my faithful Lonely Planet Guide to Japan I caught the plane with great expectations of the next ten weeks of my life.

But where was Kitakyushu and was it a nice place to stay ? My guide urged a quick exit from this modern industrial city which also had the dubious honour as the intended target for the second atomic bomb, only clouds on the day of the raid prevented Kitakyushu from becoming infamous.

Arriving at the meeting point I was issued with my identification badge and my all important dinner points which I would trade for food for the coming 10 weeks. Having mentally prepared myself for ten weeks of nothing but rice and raw fish, I was pleasantly surprised to find European food served by the Japanese chef who had been trained in France.

The first few days were spent getting to know Kitakyushu better, ie., finding the bars and making friends. The very first phase we learnt was 'Kampari' (Cheers in Japanese). In total there were 127 students from 29 countries including for the first time students from Vietnam and South Africa. These ISU students came from all walks of life; doctors, lawyers, students, engineers some of whom already specialised in the space industry, others thinking about this possibility.

Group Project: Members, including the author, of the Power Working Group on the Space Solar Power Program. *Photos supplied by the author*

Lecture Programme

The next four weeks were spent attending core lectures from nine different departments (Architecture, Business and Management, Engineering, Life Sciences, Policy and Law, Resources and Manufacturing, Satellite Applications, Physical Sciences and Humanities). Attendance of these was compulsory with the dreaded exam held just before the field trip and the pass mark set at a high 60%. The lectures themselves were of a very high standard by some of the leaders in their field. A feature of ISU is that each lecturer is assessed by the students.

Being from an engineering background I learnt most from other space disciplines. For example it was here that I learnt that the UK had an Outer Space Act which was passed in 1986. This requires the British Government to regulate objects that its nationals launch into space- it is just a pity they we do not make use of it more often. The personalities of the lecturers also added to the enjoyment of the lecturers with various methods being used to keep the students awake and interested, the most famous being the legendary Scott Madry's Mexican Wave. During this programme we found out that the recession in the space industry was global and had even affected Japan. Part of the ISU message was that co-operation between countries in space is necessary in order to avoid duplication of efforts and minimize the global cost of man's exploration and exploitation of space. With such a high number of space professionals attending ISU we also had a golden opportunity to discuss the implications of events in the space industry as they were happening.

Tanegashima Island Trip

Once we had taken the dreaded Exam, it was off on the field trip down to Tanegashima Island, way down off the south coast of Kyushu island. Tanegashima Island is used by the Japanese to launch the H1 rocket and in the future is the intended launch site for the HII. We were allowed up the launch tower and within the tracking complex which was very impressive although I must admit this was my first visit to a launch complex. An added bonus was the very hot climate and the beautiful beach which was adjacent to the complex-it must surely rate as one of the most beautiful launch complexes in the World. No bothersome tourists or crocodiles to worry about and a little further out to sea were corral reefs with some very exotic fish to watch.

During this trip we also learnt about the rigidity of the Japanese mind-after a gruelling 10 hour journey we were given 1 hour and 10 minutes on the beach and no longer!

Group Project

Back in Kitakyushu we settled into our projects. Two projects were on offer this year: Space Solar Power Program (looking at beaming solar power to the Earth) and ISUnet (looking at the future communication networks required for the permanent ISU campuses). I, like the majority of students, selected the Space Solar Power Program which was to look at the issues surrounding the use of space solar power and propose a well balanced and thought out implementation program. We soon found out why this project was selected since the Japanese are one of the World leaders in this area of research, having already performed a number of experimental demonstration missions.

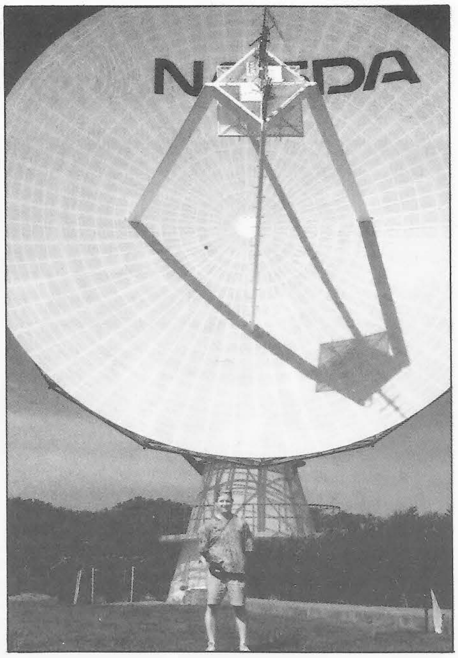
All the students were able to participate in some way depending on their speciality: from the viewpoint of engineering (how shall we collect and transmit the power?), manufacturing

(where will the materials come from?), life scientists (will the beam damage organic life ?) to the humanity students (do we need this ?). At the end of the project, a rather impressive 500 page report was issued which showed the importance of group dynamics to accomplish tasks in such a short period of time. The project also showed the dedication of the ISU students who even out-worked the Japanese, working 12 hrs/day, 7 days per week- but hell it was fun !

While we were working on the group project, we also attended a series of advanced lectures which allowed the students to specialise within their own field and to meet the world leaders in their subjects.

Entertainment ISU style.

During the course a number of cultural evenings were held. At these, students from countries (or group of countries) would entertain and educate us about their own countries and cultures. This usually started with a meal before entertainment would be provided. The BRITS being good Europeans took part in EUROPE night where our culinary delights of Spotted Dick and Fish & Chips took most people's palates by surprise.



Peter Harris at the Tanegashima Tracking Station.

ISU in the Future

This year's ISU represented the completion of the first five year plan which had the aim of establishing ISU as a viable institution. Looking towards the future there will remain the successful summer sessions (1993 in Huntsville, Alabama) plus a permanent campus and a network of affiliate campuses. At present ISU is selecting the location of its permanent campus where students will be able to undertake a one year MSc in Space Studies. The short list of potential sites are: Kitakyushu in Japan, Strasbourg in France and Toronto in Canada. The affiliate Campus will supplement the main campus providing more specialise courses in the different space disciplines.

By attending ISU you will meet some of the present and future space leaders who will help determine the future direction of the space industry. You will also learn a great deal about the different elements within the space industry, from for example the latest issues in Space Physics to the significance of Cosmic fish in the understanding of why Man has the urge to explore Space. But this is not all ISU is there for. It is about participating in the ISU experience working with students from differing backgrounds all united in their desire for the peaceful use of space. I urge anyone who has a vision of the future of space to share it with the students at ISU.

Correspondence

Support for MARS-94 Mission

Sir, I am writing to suggest that the Society mark its Diamond Jubilee by entering the world of 'hands-on exploration of space' with a grant to the MARS-94 mission described in the December 1992 issue. There is adequate precedent for the private exploration of space - British radio hams have contributed tens of thousands of pounds to build satellites which are orbiting the Earth right now.

The penetrator is a new development in interplanetary spacecraft and the electronics unit is its heart and brain. This vital component is being developed and built by British scientists and sadly it would appear that our government is not supporting this work. What better way to celebrate 60 years of the British Interplanetary Society than to send British equipment on a pioneering interplanetary mission?

JOHN FRIZELL
E. Sussex, UK

Not a Rocket Society

Sir, There was talk some years ago about changing the name of the Society to British Rocket Society - this was, rightly, strongly resisted. But the Society seems to act as if it was a rocket society. We are the British INTERPLANETARY Society. Rockets are only a means to an end - and a poor one at that.

More emphasis should be placed on the planetary side and less on the rocket. Planets round other suns, terraforming, living on hostile worlds .etc.

J.K. MAYNARD
Huddersfield, UK

Pop Songs and Outer Space

Sir, I was interested to read Mark Hempsell's letter in the December 1992 issue of ***Spaceflight*** magazine regarding pop songs and outer space. There are a few other notable records that have been in the charts that he did not mention.

I can vividly remember playing "TELSTAR" by the Tornadoes at full blast on my Dansette record player in the 60's. With reference to Miss Archer's "Sleeping Satellite" there was Jonathan King's record titled "Everyone's gone to the Moon". Also looking forward to the future were the Bonzo Dog Doo-Dah Band singing about "The Urban Spaceman" and in the search for extra-terrestrial intelligence were the Carpenters with "Calling occupants of interplanetary craft".

We should not forget NASA's own attempt to break into the interstellar record charts with its own (1½ hour) long playing record called "The Sounds of Earth". Carried on board both Voyager spacecraft launched in 1977 these records contain recordings of greetings in 60 different languages as well as natural sounds including a song sung by a humpback whale! Although only two copies of the record have been made since it was first recorded, if orders ever start coming in from an alien civilisation the sales figures can be expected to be truly astronomical!

MARTIN CRESDEE
Oxon, UK

Space Travel has Produced Almost no Music

Sir, I am writing in response to your article in the December edition of ***Spaceflight*** concerning Ms Tasmin Archer and her song 'Sleeping Satellite'.

In the past, of course, ballads and folk-songs have been used to record Man's various achievements - all those old Western ballads and those innumerable sea-shanties - some of which are still being sung today - usually with choruses of 'heave-away, haul-away'. (On the old sailing ships, the songs were used as timing devices, to get all the crew heaving and hauling at the same time.)

Space travel has produced an immense amount of fiction, some art (Chesley Bonestell was mentioned in the December issue), a little poetry, but almost no music unless you count things, like Also Sprach Zarasthustra, which have become linked with Space travel after their writing and things like the Planets Suite, which deal with Space and not Space travel.

Space exploration, and colonisation, should provide sufficient grandeur, scope, emotional potential, etc to provide the foundation for almost any form of art. (Some readers may be aware that the singer John Denver is a member of the American National Space Society's Board of Governors.)

Ms Archer is to be congratulated on helping to bring about a long awaited advance - one which I hope she, and others, will be able to build on, advancing the aims of the BIS at the same time.

P.W. DAVEY
Dorset, UK

Long List of Space-Related Music

Sir, I was interested to read the article by Mark Hempsell (***Spaceflight***, December 1992, p. 401) reporting on the no. 1 song 'Sleeping Satellite' by Tasmin Archer. Good as it was to see a space-related song doing well, I feel that Mr Hempsell has missed a wealth of material in contemporary music that addresses space issues. This seems to stem from the fact that many people see the 'charts' or Top 40 as the focus for modern music. This might have been true in the 1960's, but since then musicians realised that more people were buying albums than singles. So if one defines successful songs as having large exposure to the music buying public, then 'Space Oddity' and 'Rocket Man' (the two other singles mentioned by Mr Hempsell) are far from being the "... only two successful songs (that) have begun to address space issues...". I would say that rather than being "vaguely negative", David Bowie's 'Space Oddity' was strangely prophetic. The 1968 song dealt with the isolation of a stranded astronaut; Apollo 13 flew just two years later and we all know what could have happened then.

There have been all kinds of music written with a space theme, ranging from simple pop songs and instrumentals in the 1960's to advanced synthesized works and thunderous hard rock. Maybe Mr Hempsell would like to check on some of these space-related works:

The Rolling Stones	- '2000 Light Years from Home'
Jimi Hendrix	- 'Third Stone from the Sun' (both 1960's)

These were followed by one of the first space-rock acts concentrating on space travel - Pink Floyd, who wrote the following pieces over 1967-68: 'Astronomy Domine', 'Interstellar Overdrive' and, Set the Controls for the Heart of the Sun'.

In the early 70's David Bowie was back with 'Starman', as well as science-fiction buffs' Hawkwind who often wrote with space themes in their lyrics: 'Earth Calling', 'Children of the Sun', 'Spiral Galaxy 28948' and 'Space is Deep'.

A band called Rush wrote '2112', Cygnus X-1' and in 1982 a song titled 'Countdown', their personal account of the first Space Shuttle launch. Throughout the 70's and 80's, a stream of 'space' music continued via synthesizer, pop and rock:

Vangelis	- 'Pulstar', 'Albedo 0.39', 'Cosmos'
Jean Michel Jarre	- 'Rendezvous IV'
Brian Eno	- 'Apollo Atmospheres'
Jeff Wayne	- 'War of the Worlds'
The Police	- 'Walking on the Moon'
Electric Light Orchestra	- 'Ticket to the Moon'

There are many more, these are just a sample which I believe show that the Tasmin Archer song was just one in a long list of music relating to space. Space consciousness is alive, well and here to stay in contemporary music.

M. PHILLIPS FBIS
Kent, UK

A Fast Pulsar in the Making?

Sir, The article on SS433 - "Weighed and Found Wanting" [1] is yet another page in the annals of this mystery object which is (so far) unique - although Circinus X-1 shows some similarities.

Originally the companion star was thought to be a hot giant (10-20 solar mass) in a 13-day orbit about a neutron star or black hole of about 3 solar masses. These figures were based on initial spectrum measurement of the main star. Later measurements suggested a 16 solar mass item. [2]

Now, using the 3.5 metre New Technology Telescope in Chile, European astronomers have obtained a series of precision spectra - more precisely those of helium. These precise measurements have drastically reduced the calculated mass of the companion star to only 3 solar masses [3,4]. This in turn cuts down the mass of the compact object to only 0.7 to 0.9 solar mass. This means it is *definitely* a neutron star not a black hole.

However, this further measurement does change the expected life-time of this weird binary system. Originally the 16 solar mass model could not have lasted more than a few million years. Now, the revised measurements suggest a lifetime of possibly a billion years or more - which puts a very different outlook on its future. As the 3 solar mass companion moves up the Main Sequence it will evolve to a Red Giant and finally shrink to a White Dwarf. The star's material will be increasingly "gulped down" by the neutron star which might increase its rotation period (presently unknown) and most certainly change the radiation spectra. The two relativistic "jets" should increase in intensity during this period.

Eventually the companion start will shrink down to a White Dwarf of approximately 0.6 to 1.0 solar mass and possibly drift away from the neutron star and move into a wider orbit with a longer period than at present.

The neutron star itself may possibly increase its spin period and become a fast pulsar. At present we do not know if the neutron star *is* a pulsar simply because the axes of the relativistic jets and any pulsar beams do not coincide. Consequently any pulsar "flashes" are not directed towards Earth.

Whatever its future SS433 continues to be an enigmatic puzzle and is best summed up by an anecdote from [2]. On the notice board at the Royal Greenwich Observatory someone had mistyped the object as SS443. Underneath the error a frustrated anonymous astronomer had scribbled "Oh God - not another one!!".

A.T. LAWTON
Sussex, UK

References

1. "Weighed and Found Wanting", Astronomical Notebook, *Spaceflight*, December 1992, p.388.
2. David H. Clark, *The Quest for SS433*, published by Adam Hilger, Bristol 1986.
3. *Nature*, Vol. **253**, p. 329, 1991.
4. *New Scientist*, Vol. **132**, No. 1796, p. 22, 1991.

Historical Space Video Recordings

Sir, I write in response to the recent spate of correspondence published by ***Spaceflight*** regarding the fate of television coverage of the Apollo missions. Mat Irvine's most recent response (December 1992 Issue) to the letters of Ian Broadbent and George Spiteri conveniently ignores the fact that the BBC's (and for that matter ITN's) coverage of the Apollo missions is part of broadcasting history, and for this reason alone deserves to have been treated with better respect. If these live television accounts of each mission are no longer of interest, why is it that several of the BBC's own Horizon programmes have included many excerpts from the BBC's coverage as broadcast at the time? Why for that matter should the American CBS network have produced a commercial video focusing almost entirely upon its famed coverage of the Apollo 11 mission?

If Mr Irvine is a little bemused as to why the BBC and ITN coverage of the Apollo missions should continue to generate so much interest so long after the event, perhaps I can offer an explanation. The Moon landings - and in particular the voyage of Apollo 11 - united the people of the world in a way unlike any event before or since. Certainly, no other journey into the unknown - be it Scott's trek to the south pole, or Lindbergh's solo flight across the Atlantic - succeeded in capturing the imagination of the ordinary man on the street as the Apollo Moon landings, and the medium through which the general public became so intimately "involved" in the Moon landings was of course television. Given this fact, is it not reasonable that British space enthusiasts should still hold the domestic networks coverage of the Apollo missions in such high esteem? As far as many British viewers are concerned, names like James Burke, Peter Fairley and Geoffrey Pardoe were as much a part of the Apollo programme as those of Frank Borman, Mike Collins and John Young. While this perhaps grossly overestimates the importance of the broadcasters - who were themselves merely observers of events - at the time they were part and parcel of every Apollo mission, and for this reason are inseparable in many people's memories of these historic flights.

While Mr Irvine is quite correct in stating that the official NASA footage is of greater importance and remains freely available, invariably the presentation of this footage tends to be a little bland and rarely tells the full story by itself. For example, I recall (via an Horizon programme of the early 1980s) a moment from the BBC's coverage of Apollo 13 mission. As the panel of experts waited for the capsule to come through the communications blackout of re-entry, the camera focused upon James Burke - head bowed, fingers tightly crossed as he awaited confirmation of the safety of the crew. To my mind, the fact that a professional broadcaster should act with such obvious anxiety says more about the tension and drama of the moment than many documentaries made subsequent to Apollo 13, most of which have of course relied almost exclusively upon "real" space footage.

This business of having "captured the missions on early video recorders" has all arisen because neither the BBC or ITN appears to have made much of an effort to preserve this valuable material for archival purposes - a viewpoint which is perhaps confirmed by the fact that the BBC is itself in some doubt as to what it actually holds in its own vaults. Perhaps our desire to see some of this footage again is nothing more than a self indulgent nostalgia trip - however, for the benefit of future generations to come, I only hope that the BBC and ITN have not been so careless in discarding their coverage of the fall of the Berlin Wall and the Moscow Coup, just because these events happened to be broadcast live! Bearing in mind that television reporters are always prone to tell us, the viewers, when real history is unfolding on our screens, it would be incongruous if the television networks did not themselves make a concerted effort to preserve such moments for posterity.

DARREN L. BURNHAM
Oxon, UK

Sir, In response to Mat Irvine's letter in the December issue of ***Spaceflight***, my concerns are for Live Studio Footage with comments and observations made to events as the Mission unfolded. The BBCs Coverage In particular had many experts to comment in a unique way almost on any aspect that the presenter could wish for.

As an example I have just finished listening to an audio only, reel to reel recording of BBC Apollo 16 coverage, in which James Burke is joined in the studio by Eugene Shoemaker, one of the chief geologists, responsible for training of the astronauts and selecting the Apollo landing sites. Comments made by such a person, in real time to live images from the lunar surface, were unique and can be used as a major source of material on how and why each site was chosen. Dave Scott, the Apollo 15 Commander, who only months earlier had explored the Hadley Apennine front, was also on hand in the studio reacting in the light of his own mission, to Young and Duke's lunar surface activities. One example was his reaction to the lunar rover seat belt modifications made to the vehicle after Scott and Irwin's difficulties with the same item on Apollo 15, none of which can be found in any publication or account of Apollo.

Many faces and personalities formed the BBC Apollo coverage team, each giving their own individual thoughts and opinions, Patrick Moore, James Burke, Geoffrey Pardoe, and Tony Nichollson all blended together to draw off each others knowledge and expertise, in a way that drew the audience in. The shots of the presenters crossing their fingers during the re-entry of Apollo 13, is a particularly memorable scene, and the heart felt "they've made it" from Patrick Moore must have been echoed by the millions watching up and down the country. Again, material that is not available in any account or post mission write up.

To sum up, these programmes of live coverage, represent how a generation reacted to this almost science fiction event, and is just as important as the actual NASA tape.

IAN BROADBENT
S. Yorkshire, UK

Sir, I was interested to read Mat Irvine's letter in the December issue of ***Spaceflight*** (p.400) regarding Video Recordings of the Apollo missions. I hasten to add that I am not in the least "worried" - to use Mr Irvine's words - about these recordings.

I was simply pointing out that I was not surprised that there are hardly any recordings of the "live" coverage of the lunar landings and furthermore, I wished to inform members and other interested parties that I had taped these missions out of personal interest.

GEORGE A. SPITERI, FBIS
West Midlands, UK

New Ion Motor and MHD-Generator

Sir, I refer to Mr D.G. Fearn's article on Ion Propulsion (***Spaceflight***, October 1992, p.324). I would like to inform you that I have invented a new high power ion motor: Collective Ion Accelerator Propulsion Engine and its MHD-energy source. This invention represents an improvement of the early ion rocket motors in producing very high velocities of the exhaust mass and a medium/high thrust level, the mass of propellant ejected being quite small. (UK Pat. Appl. 2235332 A).

Collective Ion thrusters could be one of the important developments for advance space transportation systems and also manned spacecraft in the future.

URPO T. HAYRINEN
Vice-President of the Finnish Astronautical Society

Society News

ESA Video Awards

Mnemonic Competition Results

The results are announced of the winners of the *Spaceflight* Mnemonic Competition held in cooperation with the European Space Agency. *Norman Longdon* **of ESA writes:**

It was great fun reading the many entries for the competition: it was much more of a headache picking the winners from such diverse subjects ranging from space exploration to the supernatural through industry and vegetarian diets.

Entries came from five countries (one entry in French) and there were several from women readers, although the contestants were predominantly male. Several came up with the same or a very similar mnemonic "My Very Easy Method: Just Set Up Nine Planets".

Now for the winners:

1st Prize goes to Tim Cunningham from Oban in Scotland for "Man's Visionary Exploration May Just Survive Using Nuclear Propulsion". I liked the combination of fact and prophecy, and the easy rhythm of the phrase.

I decided that two vegetarian entries were of equal merit, and so both will receive the two videos that go with the second prize:

Miss Bucklard from Sevenoaks sent: "Mum's Very Economical Menu: Just Salad Upon Noreen's Plate", and

Mr T.C. Ashton from Kidderminster with: "Many Vegetarians Enjoy Making Jam Sandwiches Using Natural Products".

The five consolation prizes go to:

Mr W.G. Maxwell from Banffshire: "My Very Engaging Manager Just Signed Up Nine Players".

Mrs Y. Cooper from Cheam: "More Vigilant Eyes May Just See Unknown New Planets".

Mrs K.E. Evans from Ilford: "My Vicar Eagerly Ministers Jesus Salvation Unto Needy People".

Mr G. Buckley from Rochdale: "Meteor's Violent Ending May Just Stimulate Unusual Natural Phenomena".

Mr D.G. Gilbauh from North Yorkshire: "Many Very Exciting Missions Just Speed Unnoticed - Never Praised".

My thanks to all the contestants. I hope you had as much pleasure composing your mnemonics as I had in reading them

All winners will also receive a copy of ESA's latest publication "European Space...for exclusively peaceful purposes".

Society Videos

New additions to the Society's collection of videos are announced (see inside front cover). A recent shuttle mission that is now available is STS-49, launched on 7 May 1992. The Society already has an extensive collection of historical videos and this is now augmented with a video on the Apollo 10 mission.

Council Report

At the Council Meeting following the Annual General Meeting, Mr A.T. Lawton was re-elected President for a third term, Mr Martin Fry was elected Vice-President for a second term and Mr C.R. Turner for a third term.

A decision was made to renew the Society Committee Working Group structure and a new initiative was taken to examine potential areas of activity for a Technical Study Group. Members and Fellows are invited to participate in this by submitting ideas for potential but realistic projects, but bearing in mind limitations of time and cost.

1993 Membership Renewal

We thank the many members who have renewed their Society membership for 1993. Subscriptions fall due on 1 January 1993 and it is now an urgent matter to send outstanding dues to the Society if magazines are to be despatched on time. Please ensure that your renewal form has been dealt with and in case of difficulty or uncertainty please contact the Society.

Membership Cards

Membership Cards for 1993 carry a new design based on our Comet Logo, which is the Society's Heraldic Badge granted to the Society by the College of Arms under Warrant in 1986.

Comets are the natural travellers of interplanetary space, journeying from its outermost to its innermost regions and also, possibly, into interstellar regions. The design, therefore, provides an appropriate symbol of the Society's aims.

In recent years Membership Cards have depicted the Society's Coat of Arms and in earlier years its Rocket Logo. Preparations are soon to be made for the supply of Membership Cards for 1994 onwards.

Comments have been received from members on each of the above designs but the Council would welcome a further feed-back on which of the three has proved most attractive, or if some further alternative should be sought.

Members interested in such matters are invited to participate in making the final choice by sending in sketches of any attractive ideas they may have.

47th Annual General Meeting

The Society's 47th Annual General Meeting was held at HQ on 15 August 1992.

Proceedings at the 47th AGM

The Society's 47th Annual General Meeting was opened by the President who drew attention to the 1991 Report, published in full in the July 1992 edition of ***Spaceflight***. There were, however, one or two additional comments to be made. One was that Space '92 had been cancelled, regretfully, owing to a much depleted attendence, due to the recession, and our need to avoid financial loss.

The second was the appointment of Ms S.A. Jones as the new Executive Secretary who has now officially taken over the duties formerly carried out by Mr Carter, who had moved to the post of Special Projects Officer.

After the Report had been adopted, the Executive Secretary introduced the Balance Sheet and Accounts to 31st December 1991. She pointed out that the Society's capital position was very satisfactory and that, with the continuing support of members, all the planned building work had been carried out without the need either to obtain a bank loan or to use any part of our normal subscription income. Practically the whole of the costs to date had been covered by means of gifts and fund-raising activities and, eventually, the whole would probably be met in this way. However, the

recession had affected our 1991 accounts, not so much by way of reduced subscriptions but through lack of advertising and similar support. These proceeds had always been used to offset the cost of publications so the result was that, when this extra income fell away, the share of publication costs which the Society had to bear was greatly increased. Many magazines heavily dependent on advertising had been forced out of business for this reason. The Society, however, has been lucky and is still strong, though these increased costs had still to be faced and have absorbed our previous surplus. It remained very important to watch this position and to spend our income with even greater care, in the hope that conditions would soon improve again.

The President added that the final phase of the building work had now been completed and that at no time had it been necessary to call upon the £30,000 option loan authorised by members at earlier Annual General Meetings. The Society was now in the final stages of its refurbishment several years ahead of the date first envisaged. The remaining work included meeting additional fire prevention requirements, likely to be completed early in 1993.

It was resolved that the accounts be adopted and also that the Society's Auditors be reappointed at a remuneration to be agreed by the Council.

Four vacancies in the Society's Council were to be filled and, since only four nominations had been received and all nominees were willing to stand, the matter of elections could be resolved at the meeting without recourse to ballot. The four nominees, all retiring Members of the Council, were Mr A.T. Lawton, Dr R.C. Parkinson, Professor I.E. Smith and Mr C.R. Turner.

It was proposed and seconded from the floor that these nominees be re-elected to fill the vacancies.

The meeting concluded with a lively discussion on the affairs of the Society, most of which has since been discussed more fully in the correspondence columns of ***Spaceflight***.

The President concluded the meeting by adding that comments from members were always received with interest.

Endnote

For most organisations incorporated under the Companies Act, the AGM represents the only opportunity for shareholders, with money at risk, to learn about the affairs of the company involved.

This situation does not apply to our Society which is incorporated without share capital and for which discussion of the Society's affairs is not restricted to the relatively few who attend an AGM but embraces the whole membership. Discussion is conducted frequently through the pages of its magazines and each member, wherever he may be, has access to the Society without restriction to a single meeting on a single day and at a single place.

Nonetheless, an Annual General Meeting provides a focus which enables the Council to provide an overview of the work of the Society during the previous year ended on 31st December and for recording its achievements on a regular basis.

The Agenda of each Annual General Meeting is set out by Law. This is a protection to enable members to know, beforehand, precisely what matters are to be discussed and what decisions are to be made. It bars a small group from raising and deciding on other matters without the prior knowledge of everyone else.

Classified Advertisements

The attention of readers is drawn to the facility offered by ***Spaceflight*** for the placing of small advertisements relating to personal interests and needs. Society members may place adverts at the rate of 53p per word inc. VAT (non-members at £1.06 per word inc. VAT).

SOCIETY MEETINGS DIARY

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.
It may occasionally happen that, for reasons outside its control, the Society has to change the dates or topics of meetings. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always recheck the scheduled meetings in the latest issue.

6 January 1993 — 7 pm - 8.30 pm

Development of Space-Based Astronomy in the UK

Prof K.A. Pounds
University of Leicester

The enormous advances in astronomy over the past 30 years have been due, in large part, to the ability to observe the heavens from above the Earth's atmosphere. This brings advantages at all wavelengths, most dramatically in opening up parts of the electromagnetic spectrum totally inaccessible from the ground. X-ray observations are a prime example, where the availability of space vehicles has led to a new discipline, of high energy astrophysics. Examples are given from past and present space astronomy projects in which UK scientists have a leading role.

3 February 1993 — 7 pm - 8.30 pm

Nuclear Power for Deep Space Missions?

F.J. Gardner & Dr A. Stevens
Rolls Royce and Associates Ltd

Nuclear power, in the form of radioisotopes, already enables missions into deep space where solar power is weak. The fission reactor gives much more power to mission planners and platform designers. It will enhance the electric propulsion option for deep space platforms and allow power-intensive payloads to be deployed.

This talk will review the history and issues of space nuclear power, discuss emerging options and review longer term concepts.

3 March 1993 — 7 pm - 8.30 pm

Armchair Interstellar Exploration

A.T. Lawton

Although he dreams and plans, it is very unlikely that many men will undertake manned interstellar flight. For those who will never go to the stars - the stars must come to him.

Developments in technology e.g. interferometry, large apertures, new types of high resolution detectors and high fidelity data links will enable this to happen.

As of now they allow us to see solar cycles on other Sun-like stars, detect planetary dust clouds around them and deduce the possible presence of Jupiter like planets.

These techniques can be extended with precision spectrometry to form a catalogue of stars with planetary systems closely resembling our own Solar System.

This is Armchair Interstellar Exploration whereby if we do go, or send a one way robot as proxy, we will have maximum chance of success in locating other life forms.

17 March 1993 — 7 pm - 8.30 pm

Mission Control and Control Centre Operations

D.E.B. Wilkins

The lecture will discuss spacecraft opertions in general, the technology involved and the practice of operations since the early days of space flight.

The lecture will not dwell on the historical aspects of spacecraft control though references will be made to the significant advances achieved in those early years, 1957 - 1969.

The lecture will be presented in three parts: Past, Present and Future, and will be based on the experience and activities of the speaker in the fields of Spacecraft Control and Systems Engineering.

The early NASA Manned Mission control methods will be briefly discussed and the ESA experience in scientific and applications missions described in some detail to expand discussion on Mission Control.

7 April 1993 — 7 pm - 8.30 pm

Cassini

Dr C. Cochrane

Cassini is a project planned by ESA and NASA for a spacecraft to survey the planet Saturn and its environs. During the journey to Saturn, fly-bys and investigations will by made of asteroids and Jupiter. After arrival at Saturn the spacecraft will orbit the planet for a further four years, using remote sensing to examine its satellites, rings and the planet itself. A sophisticated probe will be released in the first orbit to land on the mysterious moon Titan, to explore its atmosphere and surface.

The presentation will describe the scientific objectives of the mission, its trajectories and explain the engineering problems of the Titan Atmosphere Probe, concluding with a review the feasibility of the proposed solutions and present the innovative features of this fascinating mission.

5 May 1993 — 7 pm - 8.30 pm

Results from ERS-1

Dr G.E. Keyte
DRA Farnborough

The European Space Agency's ERS-1 satellite was one of the most complex remote sensing satellites ever launched. Despite its complexity, it has functioned almost perfectly since launch in 1991 and has enabled a wide range of research and application projects to be undertaken.

This paper briefly describes the main characteristics of the ERS-1 instruments and gives an account of their 'history' since launch. Some of the main results obtained from each of its instruments are reviewed, covering both the two microwave instruments (the Active Microwave Instrument and the Altimeter) as well as the instrument provided by the UK, the infra-red radiometer (ATSR). It will conclude by reviewing the future development of microwave remote sensing satellites after ERS-1.

SYMPOSIA & CONFERENCES

12 June 1993 — 10 am - 4.30 pm

Soviet Astronautics

This programme will include the following topics: New Developments in Soviet Cosmonautics, Cosmonaut Teams, Soviet Programmes in Historic perspective.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Offers of Papers: Authors wishing to present papers should contact the Executive Secretary.

Advance Registration is necessary.
Registration: Forms are available from the Executive Secretary. Please enclose a sae.

15 - 17 October 1993

SPACE '93: Space Initiatives

This Special Society two-day meeting to commemorate the Society's Diamond Jubilee, 1933 - 1993 will include updated versions of many of the papers originally scheduled for Space '92 but which were carried forward when Space '92 had to be deferred owing to the reduced support arising from the current widespread recession.

The main Technical Sessions will consider past, present and future initiatives in space exploration.

Offers of papers are invited. Please contact the Executive Secretary.

Advance Registration is necessary.
Details of the Programme and Registration Forms will be available from the Society in due course.

VISITS

31st March 1993

London Teleport
(Isle of Dogs)

A one-day vist with briefings and tour open to a limited number of members interested in the EUTELSAT and similar programmes.

Pre-registration is necessary. Details of programme and Registration forms are available from HQ on request.

21 May 1993

Royal Aircraft Establishment/Defence Research Agency
(Farnborough, Hants)

A one-day visit with briefing and tour open to a limited number of members interested in remote sensing, advanced propulsion systems etc.

Pre-registration is necessary. Details of Programme and Registration forms are available from HQ on request.

LIBRARY

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. Membership cards must be produced.

2 WAYNE

JOIN THE BRITISH INTERPLANETARY SOCIETY

When you join the British Interplanetary Society *Spaceflight* will be mailed directly to your home address each month, hot off the press.

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The International Magazine of Space and Astronautics

Lunar Development

Contributors: Darren Burnham ● Mark Hempsell ● Hermann Koelle

STS-52 Report

My Visit to Baikonur

By *Christopher Gainor*

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Spaceflight

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Front Cover: *A robotic unit to extract gases from lunar soil by Artist* John Andrews.
Wisconsin Center for Space Automation and Robotics, a NASA Center for the Commercial Development of Space.

My Visit to Baikonur

Ready Access Provided to Launch Pads, Assembly Buidlings and Other Facilities

It is only in the last two years that it has been possible for tourists to go to the Baikonur Cosmodrome to see the Russian space programme in action. Because of the high cost, limited accommodation and often spartan conditions, those who have so far taken the trip have been either enthusiasts or professionals. Among the enthusiasts has been *Christopher Gainor*, BIS Fellow, who visited the Baikonur Cosmodrome and associated space facilities in the Moscow area at the time of the launch of Soyuz TM-15 in July 1992. He writes about his trip and observations for *Spaceflight* readers.

BY CHRISTOPHER GAINOR
British Columbia, Canada

In the Energiya Assembly and Test Building. Note the nose fairings for Energiya strap-on rockets. *All photos supplied by author*

I joined an American-based group of 24 to see the launch of Soyuz TM-15, which had on board Russian cosmonauts Anatoly Solovyov and Sergei Avdeyev, and French cosmonaut Michel Tognini. Also at the launch was a large delegation from France, including a group of young space campers from the space camp operated by former French astronaut Patrick Baudry.

Like many in the French group, we stayed in accommodation within the grounds of the Cosmodrome near the Soyuz pad, rather than in Leninsk. We flew to Baikonur from Moscow on a chartered Aeroflot jet with officials from NPO Energiya.

Near view of the Soyuz pad at Baikonur the day after the launch of Soyuz TM-15.

The launch of Soyuz TM-15 shortly after noon local time on 27 July 1992 was of course the highlight of the trip. The Soyuz rocket rose on its bright flame into clear skies and was visible for about two minutes, disappearing before staging had taken place. Because we were viewing the launch from about a kilometre away, a fifth of the distance of the closest vantage point permitted for shuttle launches at the Kennedy Space Center, the sound from the five rocket engines could be heard before the rocket moved or smoke appeared. The degree of light and noise from the Soyuz was less than that generated by the US shuttle, even though the shuttle is viewed from a greater distance.

The next day, we were allowed to wander around the Soyuz launching pad. The flame pit was full of debris, including discarded nuts, bolts, wrenches, screwdrivers, instruments and other metal parts. We were told the flame pit is only cleaned out once a year, in contrast to the much more stringent American requirements. We were shown the Soyuz assembly and test building on the eve of the launch. Inside was the Soyuz TM-16 and the Progress M-14 spacecraft, along with a Progress recoverable capsule.

The same day as the Soyuz launch, a Proton rocket had been stood up on its launching pad for the launch three days later of what we were told was a Gorizont satellite. We went to the Proton launch area and were allowed to walk around the launch pad to within a few metres of the rocket. While the Soyuz launch complex is within view of two of the Energiya launch pads, which were originally built for the N-1 Moon rocket, the Proton pads were more than a half hour drive away. This distance was apparently dictated in part by the Protons being produced by a different design bureau than the other rockets, which came from Sergei Korolyov's design bureau. This division persists today. NPO Energiya markets Soyuz, Energiya and Buran, while the Khrunichev Enterprise markets Proton.

Our tour included the Energiya and Buran facilities. The gigantic Energiya assembly building contained in its three bays a large number of Energiya strap-on boosters, plus Energiya core stages. This was the only building where we were required to put on white smocks. We were told that an Energiya is slated to launch a "communications platform" next year.

Inside the nearby Buran assembly building, we saw the Buran-1 and Buran-2 shuttles, along with two test articles. One was used for electronic testing of the shuttle and facilities, while the second was used as a transport test article, much like the US shuttle Enterprise has been used in recent years. We were also shown a docking adaptor for use by a shuttle docking with Mir. Vitaly Balgarluk, identified as Buran's deputy chief designer, said the adaptor may be sold to NASA for use by a US shuttle docking with Mir. The adaptor would be installed inside the shuttle's payload bay, just behind the flight deck.

Outside the Energiya assembly building sat two huge rail transport vehicles for the Energiya-Buran combination which sits horizontally on the vehicles and is towed along twin sets of rails to one of the launch pads. A

hydraulic device on the transporter is used to stand the rocket up at the pad.

We then toured the launch pad used for the 1988 Energlya-Buran launch and later the Buran landing strip. The pad features three 25-metre-deep flame trenches, which had stagnant pools of water at the bottom. Two fixed towers stood alongside the pad, plus a third that could move away on rails. One of the fixed towers had two very thick cylindrical arms extending from the ground to the shuttle hatch level. One arm is used as a slide for emergency egress from Buran, and leads to blast rooms below the pad. The second contained a flatcar with 16 seats that carried us up and down rails inside the arm, in a manner much like the uphill portion of a roller coaster, to the shuttle hatch level. This came as a surprise to those of us expecting a simple elevator ride up the tower.

Near the three-kilometre-long runway were two skeletal metallic structures, one used for shuttle checkout and the other to mount Buran on transport aircraft.

Distant view of the Soyuz pad at Baikonur the day after the launch of Soyuz TM-15.

Just before we ended our 48 hours in Baikonur, we were shown three white quonset huts which we were told were made from unused N-1 payload shrouds.

In the Moscow area, we visited star City, the Spaceflight Control Centre, and the Khrunichev plant where Proton rockets and the Salyut and Mir stations are built. At the Spaceflight Control Centre, we met several cosmonauts, including General Pyotr Klimuk, now director of the Yuri Gagarin Cosmonaut Training Centre in Star City. In spite of the economic difficulties affecting the Russian space programme, Klimuk sounded an optimistic tone in an interview carried out with the aid of an interpreter:

"We have just signed contracts with the United States and France for future manned mutual flights", he said. "It's difficult, but the work is still very good. We have some financial problems now, but the Cosmonaut Training Centre and the Simulator Base in Star City must be ahead of the space industry so we can prepare cosmonauts beforehand.

"We were touched by the economic crisis, but as we were five years ahead of everybody, it has not had an effect on us. We stopped building new simulators and devices, but the equipment we have now is enough for today's work. I think that (Russian President) Boris Yeltsin thought about it, and maybe now we will receive some money from the state", Klimuk said.

When asked about the Soviet manned Moon Programme, Klimuk said he became a cosmonaut in 1965 and began training in that programme the next year:

"I was myself a member of the lunar crew. We had problems with the rocket carrier and later some financial problems, and the programme was cancelled.

"We began an automatic programme of lunar research. I was transferred to the transport ship Soyuz and orbital stations", Klimuk said.

Cosmonaut Alexander Serebrov, the first to use the Soviet "space bicycle" in orbit, spoke about his visit to the Johnson Space Flight Center in Houston, where he tried the US Manned Manoeuvring Unit in a simulator under the supervision of Astronaut Bruce McCandless. Serebrov pronounced the US device more powerful and equipped with a greater fuel supply than the Russian version. He also said he would like to take an Imax movie camera to Mir to make movies similar to the popular Imax films taken on board the US shuttles. Near the control centre in the Moscow suburb of Kaliningrad is the NPO Energiya museum, which contains historic spacecraft such as Vostok 1, Voskhods 1 and 2, and several Soyuz capsules, among other things.

We also visited the Air Force Museum just outside Moscow. Among the aircraft on display there was a test vehicle for the Buran shuttle. The vehicle, which was also called Buran, was dropped out of a larger aircraft and landed. It resembles US lifting body

Launch of Soyuz TM-15, July 27, 1992, 10:08 am Moscow time.

test vehicles.

At the Khrunichev plant in Moscow, we were shown Proton rockets in the final stage of construction. Alongside a Mir mockup were the Spektr and Priroda modules slated for future launch to Mir. Alexander Kondratyev, a propulsion engineer who now is the head of Khrunichev's department of foreign relations, said Protons sell for US$60 million each.

Twelve Protons a year are manufactured. "If you have constructive offers for us, we can increase this number", he said. Certainly one of the strong impressions we were left with is that the Russian space programme is trying hard to sell itself to the outside world in order to earn the hard currency needed to keep it going.

The access we were given to launch pads, assembly buildings and other facilities was much greater than is possible for anyone but VIPs in similar US space facilities. The tour was organised by Aerospace Ambassadors of Huntsville, Alabama, which is also organising cosmonaut training sessions of a week or more for foreign tourists. The Aerospace Ambassadors are also planning to send an American teacher to Mir in 1994.

Energiya-Buran launch pad, Baikonur. Note the two cylindrical arms on the right. The lower arm is for emergency escapes. The upper arm contains a flatcar used to mount the umbilical tower.

Soviet Space History

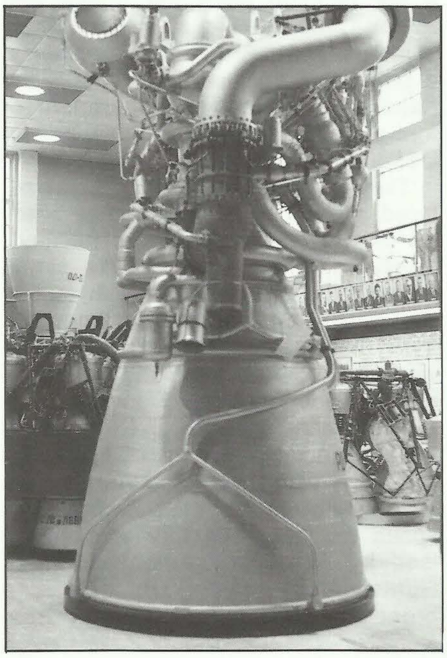
Soviet Rocket Motors On View

On recent trips to Russia, *Dietrich Haeseler* visited the museum of NPO Energomash, the largest company developing liquid rocket engines, and writes about the technical significance of two of the rocket engines on display.

BY DIETRICH HAESELER
Taufkirchen, Germany

The RD-270

Information has recently been released about the Soviet giant lunar launcher N-1. An additional piece of hardware, the RD-270 engine, may be seen at the Museum of NPO Energomash, which illustrates the depth of the disagreement between S.P. Korolyov, the chief designer of the launch rocket, and V.P. Glushko, the chief designer of the rocket engines.



RD-270, NPO Energomash Museum. *Dietrich Haeseler*

The RD-270 engine was developed by the Glushko design bureau for the first stage of the UR-700 launcher project by Valdimir Chelomey, intended to send a manned capsule around the Moon without the actual landing. This launcher was basically an enlarged Proton, the Proton itself was developed from the UR-500 project. The UR-700 project was cancelled in 1964 in favour of the N-1 launcher for a manned lunar landing, while the engine development continued.

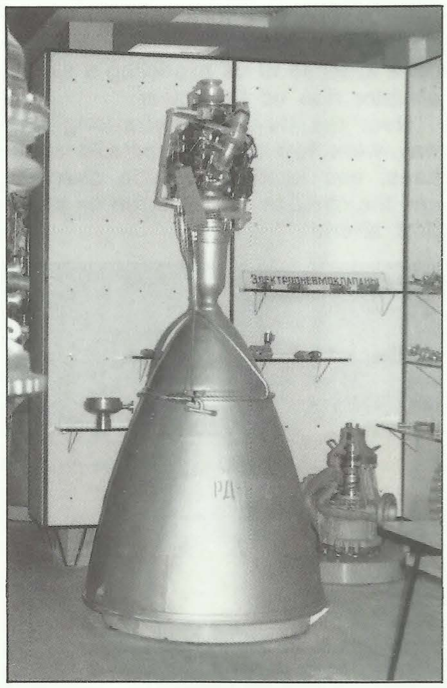
Glushko, initially selected to develop the rocket engines for this huge launcher, did not agree with Korolyov, responsible for the whole launcher project, about the concept of the first stage propulsion. They differed on the type of propellants as well as on the size of the engine. Glushko preferred few large engines using storable or exotic propellants, while Korolyov believed in the applicability of the cryogenic propellant liquid hydrogen and a number of medium size engines. When both chief designers could not find a compromise, Korolyov asked the aviation engine designer N.D. Kuznetsov to develop the various engines for N-1.

The RD-270 represents the largest engine using storable propellants. The very high chamber pressure developed in a closed staged-combustion cycle is even higher than the chamber pressure of the new large engine RD-170 built by the same bureau. It is interesting that both engine designators differ only in the first digit, which gives the propellant type, 1 for LOX/Kerosene, 2 for storable propellants. This may indicate a similarity in the design to achieve such high chamber pressure. The thrust is generated in one single large combustion chamber nearly as large as the Saturn V first stage engine F-1.

If Glushko's RD-270 had been employed in the N-1 launcher, about eight engines would have been necessary in the first stage to achieve a thrust similar to the thirty NK-33 engines, which were eventually used in the actual N-1 launcher design.

The RD-502

Another engine seen in the museum of NPO Energomash was developed by the Glushko design bureau as a test engine to check the use of exotic propellants. The RD-502 uses hydrogen peroxide and pentaborane. In principle, both hydrogen peroxide and pentaborane are storable propellants. Pentaborane is extremely toxic, but can be handled safely if appropriate



RD-502, NPO Energomash Museum. *Dietrich Haeseler*

The data below are from the data sheet for the RD-270 at the museum exhibition.

Design Organisation:	Gas Dynamic Laboratory - Experimental Design Bureau (GDL-OKB), Khimky near Moscow
Engine Designation:	RD-270
Development Period:	1962-1971
Oxidiser:	nitrogen tetroxide (NTO resp N_2O_4)
Fuel:	unsymmetrical dimethyl hydrazine (UDMH)
Propellant mixture ratio O/F:	2.67
Thermodynamic cycle:	closed staged-combustion
Number of combustion chambers:	1
Thrust:	sea level: 6272 kN (640 t) vacuum: 6713 kN (685 t)
Combustion chamber pressure:	260.7 bar (266 atm)
Nozzle exit pressure:	0.84 bar (0.86 atm)
Pressure expansion ratio:	310
Specific impulse:	sea level: 2950 N·s/kg (301 s) vacuum: 3156 N·s/kg (322 s)
Engine mass:	dry: 4770 kg wet: 5603 kg
Engine dimensions:	height: 4.850 m diam: 3.300 m

Valentina Ponomaryova's Story

On a visit to Star City, *Pierre-Emmanuel Paulis* met cosmonaut Valentina Ponomaryova, the back-up to Valentina Tereshkova, the first woman in space in June 1963. "It was a big chance for me to meet this nice cosmonaut", he writes. The meeting provided an opportunity for him to hear about her work in the following question and answer session.

PIERRE-EMMANUEL PAULIS
Ferrieres, Belgium

Left to right: Valentina Ponomaryova, Pierre-Emmanuel Paulis and Tatiana Manouillova, interpreter.

Why did you apply for a post of cosmonaut and in what circumstances?

In 1962, after Yuri Gagarin's flight, I was working at the Mathematics Institute in Moscow and had my pilot's licence. It was the very beginning of manned space flight and several people at the Institute told me: "You like flying! Wouldn't you like to fly in space?". For the first time women were to be selected and I applied for the post.

Tell me about the selection

Five women were chosen. Among these were Valentina Tereshkova and myself. All the applicants had to be pilots and be prepared to make parachute jumps. There were 400 of us at the beginning.

Why did Valentina Tereshkova become "the first woman in space"?

She was the best, especially as far as the medical examinations were concerned. They were a very important factor. The first woman into space had to be a good communist too... Tereshkova met all these conditions.

Why did you never fly into space?

At the time only one flight by a woman was planned. I'd have like so much to have gone up. I was trained and ready for a space flight. A second Soviet woman flew much later in 1982 (Svetlana Savitskaya). Those in charge of space flights were very misogynic. They only needed male cosmonauts. They only sent a woman into space because they wanted to be the first to do it.

You knew the first man in space Yuri Gagarin very well. How did you get on with him?

Yuri was not exactly a friend of mine but we met many times and often talked together. He was a real leader among the pilots and at Star City. Everybody was captivated by him and what he had done.

What was your role during Tereshkova's flight in June 1963?

I was at the launching site at Baikonur and was attending to the communications with Valentina.

What was your role after Tereshkova's flight?

With my four female colleagues we went on training until 1969. We continued to hope we would fly one day. In 1969 we stopped training and I went back to the Mathematics Institute to teach. Afterwards I taught the new cosmonauts aerodynamics at Star City. I contributed notably to the preparation of French and German cosmonauts and recently to that of the English cosmonaut, Helen Sharman.

What was the reaction at Star City when Neil Armstrong took the first step on the Moon? The reason why I ask this question is that we now know that a Russian, Alexei Leonov was to have become the first man on the Moon, a few weeks before the Americans.

I don't know if Leonov was to have become the first man on the Moon. We had a lunar programme though the government didn't tell us anything about this.

On July 21 we were very sad that the first man on the Moon was an American. When the Apollo program ended in 1972 we launched unmanned space probes to the Moon. They were called Lunokhods. It was very exciting.

Soviet Rocket Motors on View (continued)

precautions are taken. In addition, it tends to ignite itself in air. The performance, however, is higher compared to hydrazine and its derivates. (ESTEC, the technological branch of ESA, recently studied and proposed to check the use of pentaborane as a propellant for increased performance in combination with nitrogen tetroxide.)

The high pressure expansion ratio and the low nozzle exit pressure are usable only for a vacuum engine. Thus this engine was intended for an upper state of a space launcher. The thrust is similar to the thrust of the Block-D engine (85 kN), which is used in the upper stage of the Proton launcher. Use of the Block-D is planned also for Zenit and Energiya launchers. Perhaps, there were also plans for an upper stage utilising exotic propellants and the RD-502 engine.

The development was stopped due to the toxicity of pentaborane.

The data below are from the data sheet for the RD-502 at the museum exhibition.

Type:	liquid fuelled rocket engine
Design Group:	Gas Dynamic Laboratory Experimental Design Bureau
Development Period:	1960-1966
Oxidiser:	highly concentrated hydrogen peroxide
Fuel:	pentaborane
Thermodynamic cycle:	closed staged-combustion
Number of combustion chambers:	1
Vacuum thrust:	98.06 kN (10 t)
Combustion chamber pressure:	147 bar (150 atm)
Nozzle exit pressure:	0.05 bar (0.05 atm)
Pressure expansion ratio:	3000
Specific vacuum impulse:	3724 N·s/kg (380 s)
Engine mass:	dry: 132 kg wet: 140 kg
Engine dimensions:	height: 2.510 m diam: 1.180 m

The Soviet Venus Programme

A detailed account of the history of the Soviet Venus Programme by *Donald F. Robertson*, entitled 'Venus - A Prime Soviet Objective' appeared in the May and June 1992 issues of *Spaceflight*.

***Timothy Varfolomeyev* now writes to *Spaceflight* with information that has come to light in the Soviet press and books published in the last few years. "I have read the article by *Donald F. Robertson* with great interest", he says. "I believe these additional pieces of information will also be of interest to *Spaceflight* readers".**

BY TIMOTHY VARFOLOMEYEV
St Petersburg

The first Soviet interplanetary spacecraft design began in the middle of 1958 [1]. In August 1959 theoretical research on the dynamics of space flight toward Mars and Venus had been completed by the Applied Mathematics Division of the Mathematical Institute of the Academy of Sciences of the USSR. The main conclusions of this work were that [2]:

1. Upon entry into Earth orbit a boost must be used for interplanetary trajectory injection of the so-called "escape" stage together with its spacecraft.
2. A launch toward Mars could be scheduled for September 1960, the payload being about 500 kg.
3. A launch toward Venus could be scheduled for January 1961, the payload being about 800 kg.

By September 1960, the rocket system (launcher 8K78) had been prepared and tested and it was able to send a 7-9 ton payload into Earth orbit [3].

The first launch toward Venus was scheduled for the end of January 1961 and the Soviets were very much in a hurry. Therefore the spacecraft were not checked by essential factory tests [4] and the launch had to be delayed a few time because of various malfunctions [4].

General N.P. Kamanin described the launch of February 4, 1961 in his diary as follows:

> "...the third stage had entered into Earth orbit then the fourth stage together with the AMS* separated from the third stage... But a failure occurred: the fourth stage engine ignition command had not been made (apparently the timer did not work)..." [5]. And further "...the fourth stage separation mechanism failed, as it was not pressurised at the first rocket. This defect was corrected on the rocket launcher to be launched today." (12 February 1961) [5].

As to the second Venus probe (Venera-1), Kamanin wrote:

> "...lost contact with the AMS flying toward Venus on the second million kilometres of its trajectory" [6].

The figure of 23 million, 5 million kilometres and a number of others that have been mentioned are incorrect.

The first spacecraft launch vehicles were not Soyuz (A-2) but were the four-stage Molniya (A-2-e). It was the first version of the launch vehicle now known under its real code 8K78M [7]. The name "Molniya" (as also the names "Soyuz" and "Vostok") was invented by Soviet officials much later on. Therefore the "escape" stage was not the third but the fourth one.

What was the purpose of the first two Venus missions? It has been revealed in the reference quoted above that the goal was Venus impact!

> "...It is necessary for the flight to result in Venus atmosphere impact in order to explore its atmosphere and surface..." [8].

So the purpose was "priveneritsa" [5] in Russian.

It is widely known that Venera-1 (as the first Venusian probe) was carrying a commemorative pennant of the USSR. It was:

> "...a pressurised globe-float with a commemorative medal inside. The float's volume and weight had been adapted in order for it to float when in liquid" [9] (if the Venus surface should be covered by an ocean).
> "Elements of the pennant were placed under a thermal cover in order to protect it from heat during the descent through the Venus atmosphere" [9].

So it is clear what the hemisphere atop Venera-1 was: it was the thermal cover.

The next Venus "launch window" (August/September 1962) was close to the Martian "window" (October/November 1962). In 1961 S.P. Korolyov took the decision to design a unified spacecraft for exploration of both Venus and Mars. It was "Object MV" (Object Mars-Venera) [10]. There were four versions, two being Venera spacecraft: MV-1 (landing), MV-2 (flyby); and two being Mars spacecraft: MV-3, MV-4. It needs to be noted that designations "Venera-A", "Venera-B", "Mars-A"... (in the book *The Creative Legacy of Korolyov*) are not correct. They are conventional names which were used by the authors of this book instead of real codes for reasons of secrecy [11].

So two versions of the MV object were being prepared for launch toward Venus in 1962:

> "... one AMS for landing on the planet and a second one for flyby, photography and return to the vicinity of the Earth" [12].

How many Venus probes had in fact been prepared for the mission? Maybe four (two MV-1 and two MV-2) but just three launch attempts took place in 1962:

25 August	MV-1 landing
1 September	MV-1 landing
12 September	MV-2 flyby

The first probe never left Earth orbit; and according to Kamanin:

> "...the second attempt to launch the AMS to Venus resulted in failure. The first three stages worked very well as they had done during the launch on 25 August and they inserted the fourth stage together with the probe into Earth orbit but the fourth stage did not work again..." [12].

The third probe's goal was a Venus flyby but apparently it achieved no more.

After these failures two more MV versions were designed in order to provide technology test missions. They were later called "Zond". One of them was intended to flight test the Venera probe. All six MV versions have been described [10, pp.501-514].

The first Zond was launched on 11 November 1963 and it became Cosmos-21. It has been suggested that the purpose of this mission was a lunar flyby and photography of the farside of the Moon. A similar type of test took place in both 1964 and 1965. On 4 June 1964 a Zond attempt was undertaken just toward the Moon! (This probe which was not a Luna spacecraft never reached Earth orbit). It was followed by the Zone-2 launch (30 November 1964) and finally by the third "lunar" Zond (18 July 1965, Zond-3) which performed its task. This was then followed by the Venera launch series in November 1965.

As for the February/March/April 1964 Venus launches all four spacecraft were apparently of the Zond type for Venus flyby investigation. Their launch dates were as follows:

19 February	(not 26 February)
1 March	(not 4 March)
27 March	Cosmos-27
2 April	Zond-1

The first two probes never reached Earth orbit.

When the 1965 window opened the Soviets had four Venus MV objects ready for launch; apparently two were

* AMS in Russian stands for Avtomaticheskaya Mezhplanetnaya Stantsia or in English for Automatic Interplanetary Station. The name "Venera" did not exist at that time.

aimed at the planet itself and two were for flyby:

12 November	Venus-2	flyby
16 November	Venus-3	landing
23 November	Cosmos-96	landing
26 November		flyby

"...Venera-3 had already become silent on the first half of its journey toward Venus and evidence "of the impact" was determined only by calculation of its further trajectory" [13].

The last launch attempt ended in failure.

These launches marked the end of Korolyov's era of planetary explorations. In 1965 all work connected with lunar and interplanetary spacecraft design was transferred to the G.N. Babakin's design bureau.

Babakin's Veneras were much luckier. These missions are excellently described by Donald F. Robertson. One could add that the "outline project" for the second generation of Venera spacecraft was affirmed on 24 March 1973 [14].

The real Soviet code of the D-10-e launch vehicle (Proton) is now known: it was 8K82K [7].

With regard to Venera-11 and -12 they were indeed intended "to take colour pictures of Venus and to examine soil samples" [14]. But "no pictures were returned by either... All four TV objective lens covers were not removed from the TV cameras. And they did not manage to make Venus sample analyses as the soil probes had not worked as they needed to" [15].

Soviet Venera Programme Summary

Launch Date	Payload Code	Launch Vehicle	Mission	Official Designation
4 Feb 1961	1VA	8K78	Venus impact	Tyazhyolyi Sputnik (Heavy Satellite)
12 Feb 1961	1VA	8K78	Venus impact	AMS toward Venus (Venera-1)
25 Aug 1962	2MV-1	8K78	Venus landing	-
1 Sep 1962	2MV-1	8K78	Venus landing	-
12 Sep 1962	2MV-2	8K78	Venus flyby	-
11 Nov 1963	3MV-1A	8K78M	Technical test/ Lunar flyby	Cosmos-21
19 Feb 1964	3MV-1A	8K78M	Venus flyby	-
1 Mar 1964	3MV-1A	8K78M	Venus flyby	-
27 Mar 1964	3MV-1A	8K78M	Venus flyby	Cosmos-27
2 Apr 1964	3MV-1A	8K78M	Venus flyby	Zond-1
12 Nov 1965	3MV-2	8K78M	Venus flyby	Venera-2
16 Nov 1965	3MV-1	8K78M	Venus landing	Venera-3
23 Nov 1965	3MV-1	8K78M	Venus landing	Cosmos-96
26 Nov 1965	3MV-2	8K78M	Venus flyby	-
12 Jun 1967	V-67	8K78M	Venus landing	Venera-4
17 Jun 1967	V-67	8K78M	Venus landing	Cosmos-167
5 Jan 1969	V-69	8K78M	Venus landing	Venera-5
10 Jan 1969	V-69	8K78M	Venus landing	Venera-6
17 Aug 1970	V-70	8K78M	Venus landing	Venera-7
22 Aug 1970	V-70	8K78M	Venus landing	Cosmos-359
27 Mar 1972	V-72	8K78M	Venus landing	Venera-8
31 Mar 1972	V-72	8K78M	Venus landing	Cosmos-482
8 Jun 1975	4V	8K82K	Venus orbit/landing	Venera-9
14 Jun 1975	4V	8K82K	Venus orbit/landing	Venera-10
9 Sep 1978	4V	8K82K	Venus landing	Venera-11
14 Sep 1976	4V	8K82K	Venus landing	Venera-12
30 Oct 1981	4V1M	8K82M	Venus landing	Venera-13
4 Nov 1981	4V1M	8K82K	Venus landing	Venera-14
2 Jun 1983	4V2	8K82K	Venus orbit	Venera-15
7 Jun 1983	4V2	8K82K	Venus orbit	Venera-16
15 Dec 1984	5VK	8K82K	Venus landing/ Comet flyby	Vega-1
20 Dec 1984	5VK	8K82K	Venus landing/ Comet flyby	Vega-2

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Soviet Test Pilots

VADIM Y. MOLCHANOV
Tula, Russia

Valeri Menitski

Aleksandr Fedotov

A PART OF THE HISTORY of the Soviet Space programme is Project Spiral - a predecessor of the Buran programme. A prototype of the Spiral plane was called Lapot and the names of the six test pilots who flew Lapot have now been released. They were:

(i) the four Mikoyan Design Bureau test pilots: Aviard Fastovets, Valeri Menitski, Aleksandr Fedotov and Pyotr Ostapenko
(ii) the Ministry of Aviation Industry test pilot Igor Volk who later became a cosmonaut and
(iii) the Air Force test pilot Colonel Vasili Uryadov.

Pyotr Ostapenko

Aviard Fastovets

The N1-L3 Programme

The Soviet manned lunar-landing programme was highly classified until the summer of 1989 when first details were released by the Soviet newspaper *Izvestia*. Since then more information has become available and was reported by *Daniel A. Lebedev* in *Spaceflight* (September 1992, pp.288-290). The author now has further information which he provides in this short update to his previous article.

BY DANIEL A. LEBEDEV
Ekaterinburg, Russia

The N-1 First-Stage Engines

I have now received a letter from one of the N-1 launch engineers about the duration of burn of the first-stage engines. This varied from 114 to 120 seconds for different launches and was not 140 seconds as previously stated.

The Second N-1 Launch

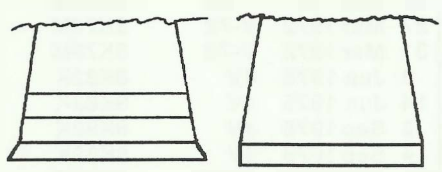
The previous N1 launch descriptions can now be augmented to provide a fuller story.

The N1 launch took place on July 3, 1969 at 23:18:32 Moscow time from launch pad number 1. Soon after ignition, when lift-off began and the vehicle had cleared the launch tower, (T + 6-9 seconds and at an altitude of about 150-200 metres) some unknown object (probably a piece of waste) that had remained in the oxidiser tank of the first stage penetrated into the pipeline (which did not have filters) and got into one of the turbopumps, causing it to explode a moment later, followed by the explosion of engine number 8 which in turn caused destruction of several of the surrounding engines.

The electrical circuitry of that stage was damaged too, causing the remaining engines to shut down. At that time the launch escape system worked and the booster stage's payload was delivered 1 km away from the launch pad. At the same time the N1 vehicle fell back towards the launch pad and a powerful explosion took place, booster and launch pad being completely destroyed. The flight duration from ignition to explosion was around 18 seconds.

The Last N1 Launch

The last N1 launch attempt took place on November 23, 1972. On this occasion the booster had a new engine compartment (the skirt being cylindrical, not conical, as previously).



N-1 Engine Compartment for numbers 3L, 5L and 6L (left) with conical skirt and numbers 7L, 8L (right) with cylindrical skirt.

The booster (serial number 7L) had more recent (and more powerful) engines plus additional "rudder" engines, that were installed on the first and second stages, a new freon fire-extinguishing system, a more recent control system (KORD) and guidance system, filters in the tanks, and several other changes. The new booster was heavier than that of the previous vehicle, but it was designed to be more reliable. Installed were a real lunar orbital spacecraft and a mock-up lunar landing module as payload.

The N1 booster lifted off at 12:18:07 Moscow time from launch pad number 2. the first-stage engines ignited without a problem and then worked well. Engine throttle-down and throttle-up passed off smoothly during the period of maximum dynamic pressure. At T+90 seconds the six central engines were automatically shut down as planned (like the first-stage central engine cut-off during a Saturn V-Apollo lift-off).

Due to a strong hydraulic impulse (which happened because of the quick cut-off) an unexpected vibration of the fuel components began in the tanks and pipelines and several of the pipelines broke. The fuel began to flow out into the hot engine compartment, causing a fire a few seconds later. (The first sign of fire was at T + 96 seconds). The fire-extinguishing system did not activate and the temperature began to rise. At T + 105 seconds a series of engine explosions began and the remaining working engines were shut down by the KORD control system two seconds later. At that time the launch escape system activated and the N1 vehicle was destroyed by range safety at an altitude of about 40 km and at about T + 108 seconds.

There remained only 7-10 seconds until the time of normal first-stage engine cut-off and the booster had a velocity of only 165 m/s less than that planned for normal engine cut-off. If the malfunctioning stage could have separated soon after KORD's command for engine shut down, the booster would still have been capable of entering low Earth orbit (a lower one than planned) and if the other stages had then worked well the mission would still have had a change of success as components of the lunar spacecraft had been tested many times previously during launches of the Vostok booster to elliptical orbit.

SPACE EDUCATION

Group Visits to Space Camp

ALEXANDER SEREBROV
Pilot-Cosmonaut, President of the All-Russian Youth Aerospace Society 'Soyuz'

Space Camp is located at the Star City facilities where all Russian and joint international teams of cosmonauts are trained for space flight. Star City is situated 40 km north-east of Moscow.

Special training for groups of young people (14 years of age and over) and adults with an interest in Space and Astronautics is now being offered under the joint auspices of the All-Russian Youth Aerospace Society 'Soyuz' and the Yuri Gagarin Cosmonauts Training Centre. The Centre is equipped with numerous simulators and there are mock-ups of the Mir orbital station and its modules in which cosmonauts will conduct their future space research work and experiments.

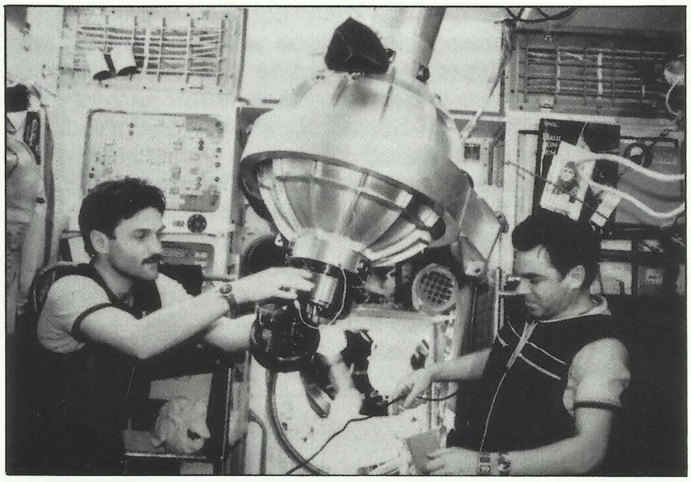
A group of students and/or teachers may consist of 10-30 persons. All training courses are held in separate groups of 5-8 persons by qualified personnel and instructors of the Training Centre as well as by Russian cosmonauts. The extensive training programme includes lectures, simulator and laboratory work. After finishing the course, participants receive a special Diploma. The programme also includes general sightseeing tours of Moscow.

Soviet Cosmonaut Numbering System

Numbers are Awarded on Landing, not on Launch

On Space School's week long stay at Star City, *Neil DaCosta* had several opportunities to talk to cosmonaut Alexander Serebrov (veteran of 3 missions Soyuz T-7, T-8, TM-8), who is President of the "Soyuz" All-Russian Youth Aerospace Society, which promotes links between space flight and schoolchildren. Serebrov, who speaks good English, is also a good friend of Russian President Boris Yeltsin and helped gain permission for the stay at Star City.

DR NEIL C. DaCOSTA
London



Cosmonauts Aleksandr Kaleri *(left)* and Aleksandr Viktorenko on the Mir complex. *Spaceview-Operations, Amsterdam*

Serebrov stated that he was the 51st Soviet Cosmonaut and not the 52nd as would have been expected. All cosmonauts have their own custom made number plates on their cars. Serebrov's number plate is 00 51 MMO.

On double checking his flight order I queried how he could be the 51st cosmonaut. He told me that it was due to the Soviet numbering system. Cosmonauts are awarded their number and plates by the State Commission when they land, and not on launching. Therefore Anatoli Berezovoy (Soyuz T-5) was launched before Serebrov (Soyuz T-7) but landed afterwards, making him Cosmonaut 53 and Serebrov Cosmonaut 51 (Savitskaya 52).

I asked Serebrov how he came to fly two consecutive missions (Soyuz T-7 and T-8). He told me that the crewing of Soyuz T-8 was originally:

Cmdr	Flt. Eng.	Flt. Res.
Soyuz T-8 Prime Crew		
V. Titov	Strekalov	Pronina
Back-up crew		
Lyakhov	Alexandrov	Serebrov

Soyuz T-8 was to have been a mission of over 2 months but, due to problems with Salyut 7, and therefore an increased workload, Serebrov replaced Irina Pronina, and Viktor Savinykh took his place as back-up. He had been Pronina's back-up for approximately 6 months. Pronina never made a flight and is now inactive.

Alexander Serebrov also told me that when he first applied to join the cosmonaut team he had to undergo two operations, a tonsillectomy and a sinus operation, before being accepted. It also appears that at a later date he underwent a further two operations on torn thigh muscles, sustained pushing a car in the snow.

On showing Serebrov a copy of his biography [1], he pointed out that he has only one child, a son Kirill born in 1969.

It was also disclosed that he hopes to fly on the American Space Shuttle, as part of the US-Russian exchange. He is an expert on the Russian man manoeuvring unit; in the event of an EVA his experience would come in handy.

Additionally I have revised the Soviet cosmonaut numbering list of flight order. Bracketed numbers indicate deviations from the Soviet listing:

1. Gagarin
2. G. Titov
3. Nikolayev
4. Popovich
5. Bykovsky
6. Tereshkova
7. Komarov
8. Feoktistov
9. Yegorov
10. Belyayev
11. Leonov
12. Beregovoy
13. Shatalov
14. Volynov
15. Yeliseyev
16. Khrunov
17. Shonin
18. Kubasov
19. Filipchenko
20. V. Volkov
21. Gorbatko
22. Sevastyanov
23. Rukavishnikov
24. Dobrovolsky
25. Patsayev
26. Lazarev
27. Makarov
28. Klimuk
29. Lebedev
30. Artyukhin
31. Sarafanov
32. Demin
33. Gubarev
34. Grechko
35. Zholobov
36. Aksyonov
37. Zudov
38. Rozhdestvensky
39. Glazkov
40. Kovalyonok
41. Ryumin
42. Romanenko [2]
43. Dzhanibekov [2]
44. Ivanchenkov
45. Lyakhov
46. Malyshev (47)
47. Popov (46)
48. Kizim
49. Strekalov
50. Savinykh
51. Serebrov (52)
52. Savitskaya (53)
53. Berezovoy (51)
54. V. Titov
55. Alexandrov
56. Volk (58)
57. V. Solovyov (56)
58. Atkov (57)
59. Vasyutin
60. A. Volkov
61. Laveikin
62. Viktorenko
63. Levchenko (64)
64. A. Solovyov (65)
65. Manarov (63)
66. Polyakov
67. Krikalyov
68. Balandin
69. Manakov
70. Afanasyev
71. Artsebarsky
72. Aubakirov
73. Kaleri
74. Avdeyev

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2. Rex Hall advised me that Dzhanibekov and Romanenko received their awards from the State Commission at the same ceremony and therefore retain their launch order despite Romanenko's later return.

The Moon Race (AND THE COVERUP) in Hindsight

Now that Soviet officials have confirmed (20 years later) that they really were in the manned moon Race with Apollo, but lied about it when they lost, it can be handy to list those Western commentators who were mistaken through a number of causes (such as bad guesses, Soviet lies and naive assumptions). Some observers perceived the "Moon race" correctly: the Russians tried to build a super rocket they called "N-1"; they built and tested a manned lunar flyby craft (the "Zond") and a lunar module; they tested lunar space manoeuvres on Soyuz flights; and only in 1969 turned their ambitions to space stations.

Many, however, during the 1960s, did not perceive that a "Moon race" was afoot. The misconception continued in the 1970s and 1980s. Now that the truth is out, we look back with *James Oberg* at some of the statements that were published during these years.

BY JAMES OBERG
Texas, USA

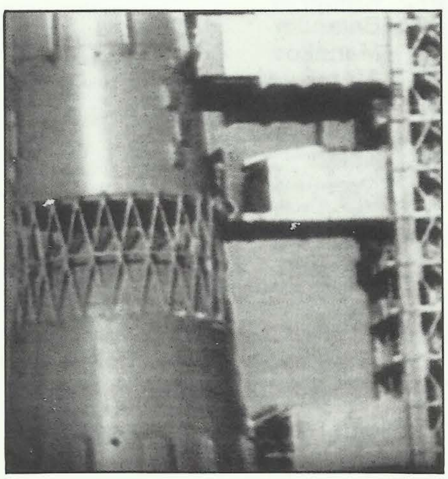
Daily Mail, London, November 3, 1963: The race to the moon is off, and good riddance to it. Mr Khrushchev's statement that Russia will withdraw is the one sensible decision since this lunatic contest between Russia and America began.

Senator J. William Fullbright, Congressional Record, November 19, 1963: The probable truth is that we are in a race not with the Russians, but with ourselves....

New York Times, editorial, "Needed: Lunar Sanity", January 27, 1964: The likelihood that the Soviet Union is shooting for a manned lunar landing this decade has been reduced by Khrushchev's own statement, by the Central Intelligence Agency's estimate of Soviet economic difficulties, and by the latest evidence of major Soviet domestic capital investment cutbacks.

New York Times, editorial, "Debating the Moon Race", April 11, 1964: There is still time to call off what has become a one-nation race and substitute a concerted international effort to search out the mysteries of space. By doing so, a portion of the money and manpower now earmarked for the moon shot could be diverted to more useful tasks.

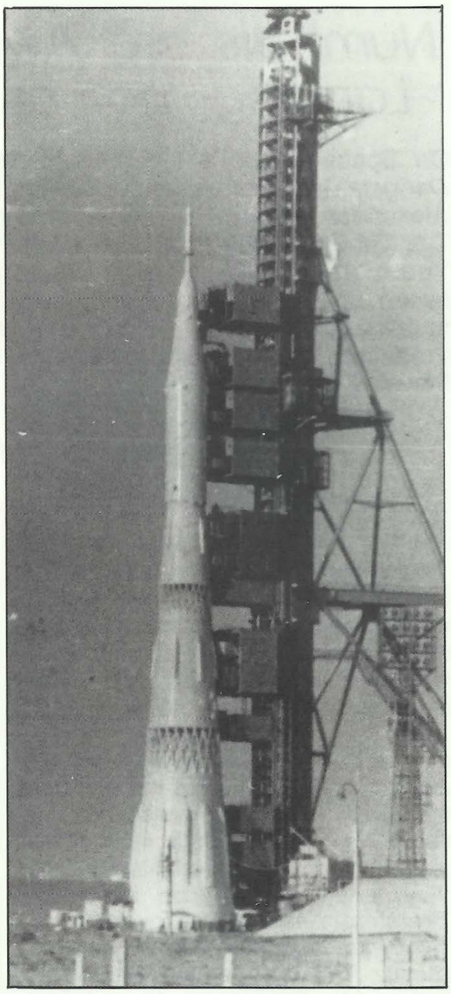
The interstage between the first and second stages and the service modules. A spherical tank is seen behind the grating. *Antipov/Lebedev*



"How Near The Moon", Newsweek, *June 8, 1964*: No evidence has appeared that the Soviet Union is building a larger rocket to go to the moon.... Many observers believe that the US is racing itself.

Dr Simon Ramo, co-founder and director, TRW Inc, manufacturer of unmanned military/civilian space vehicles: In 1965 I accepted the chairmanship of an evaluation committee set up by the Central Intelligence Agency periodically to examine intelligence data with the objective of charting Soviet progress in space. It was assumed that an all-out race to the moon was taking place... We were continually confounded by indications that the Soviets were not racing us to the moon. Our information and logical conjectures suggested that they were intent on exploring the moon with instruments, not men, exactly in line with my own preferences for a US lunar program. Quoted from *The Business of Science: Winning and Losing in the High-Tech Age*, Hill & Wang, New York, 1988.

"Reds Hint Again They're Not in Moon Race", Stuart Loory, Moscow bureau, New York Herald Tribune, September 2, 1965, based on statements by Mstislav Keldysh and G.A. Skurldin: The assumption that the Soviet space program is not aiming in that direction [manned moon flight] is becoming more and more reasonable. The Russians appear to be concentrating instead on the intermediate step of constructing a large, manned orbiting space station...



The Soviet N-1 Moon rocket at the Baikonur Cosmodrome. The absence of colour on the propulsion stages may indicate that the assembly was for testing and not for launch (as in the case of the picture in ***Spaceflight*** 1992, p.79).
Spaceview-Operations, Amsterdam

Doubleday Publishers, book jacket promotional copy for Journey to Tranquility, *1969*: The struggle to get an American on the Moon by 1970 thrived on an overwhelming fear of Russian space superiority, a fear which NASA still fosters as a challenge to American security and prestige. But by 1963 it had become clear that the Russians had little immediate interest in the Moon and that the race for space did not, in fact, exist.

John Noble Wilford, NY Times, *October 26, 1969*: According to some observers in Washington and some American scientists, the Russians may never have had a high-priority goal and timetable for a lunar landing in the same sense as the Apollo project's commitment to land men on the moon in this decade.

London Sunday Times, *1971*: It became obvious long before the Americans landed on the Moon that they

were winning the space race hands down..I. There was never the remotest chance that the Russians would get to the Moon first.

London Guardian, *1971*: Russia knew a long time ago that she cannot build a moon rocket.... 5 years ago, some Western observers were arguing that the "Moon race" was a myth... This has turned out to be the case.

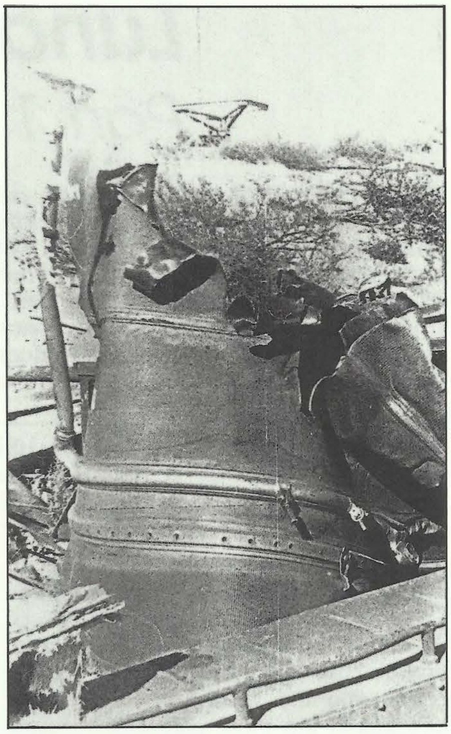
Walter Cronkite, CBS Special Report on Apollo's 5th Anniversary, July 1974: It turned out that the Russians were never in the race at all.

Parade *(Walter Scott), August 11, 1974*:
Q: During the 1960s the Kennedy Administration conducted a crash program to beat the Russians to the Moon. Now we've learned that the Russians never even came close technologically to putting a man on the Moon. Who goofed and wasted all that money? - I.F., Huntsville, AL.

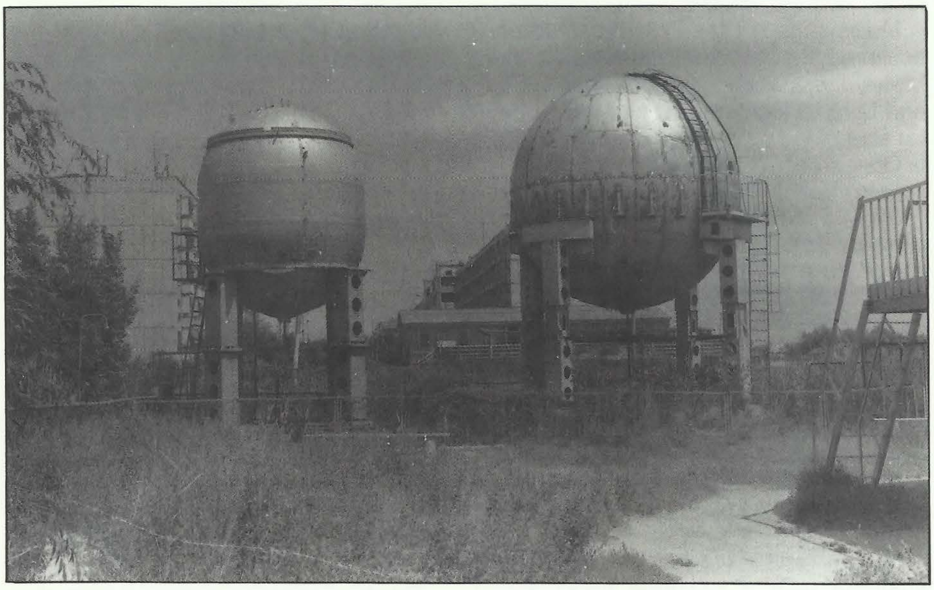
A:Whether putting an American on the Moon was a waste of money is of course arguable. That our intelligence of the Soviet space technology was faulty is not.

William Schauer (Illinois State University), The Politics of Space: A Comparison of the Soviet and American Space Programs, *Holmes & Meier, 1976, pp.172-3*: In retrospect It seems clear that by 1967 the USSR had largely abandoned whatever hopes It might have had of getting a man to the moon ahead of or shortly after the United States... The USSR had evidently backed away from any hope for a manned lunar landing.... In March of 1968, cosmonaut Gagarin died In an air crash. This probably helped to quash any remaining plans for manned lunar landings.

Chicago Sun-Times, *July 15, 1979,* *"America On The Moon: Ten Years Later", by John Camper*: As the decade progressed, it became obvious the Russians had dropped out of (or never entered) the moon race, but still we pressed on.



One of the N-1 first-stage engines. *Antipov/Lebedev*



Remains of the N-1 are to be found at Tyuratam on site (ploshadka) 113 (Energiya village) where they have been put to good use. Spherical fuel tanks have been converted into water tanks (above) and one of the shields is used as a cover for a picnic place (below). *Spaceview-Operations, Amsterdam*

Richard Hutton (University of California at Berkeley), The Cosmic Chase, *New American Library, 1981*: [In the mid-1970s] It became clear that the Soviet competition for manned space exploration had ended in the mid-1960s; since then, the United States had been racing alone.... As long as the United States still had the moon to shoot at, the illusion of a race could continue - even if we were in it alone. (pp.82,93)

Time *magazine TV special (ABC), 20th Anniversary, 1989*: Ironically, the Soviet Union never attempted to land men on the moon. They chose to concentrate on long flights.

NBC News Productions, Apollo 20th anniversary, July 1989, narrated by Leonard Nimoy: The Space race hadn't been a race at all.

Charles Murray, Apollo: The Race To The Moon, *Simon and Schuster, 1989*: By 1968, NASA was no longer worried about the Soviets landing on the Moon before the Americans....

The Cambridge Encyclopedia of Space, *edited by Michael Rycroft, Cambridge University Press, 1990*: From its early days, the main aim of the Soviet space programme has been the construction of large, permanently manned space stations orbiting the Earth.

Lunar Development, Past and

Part 1 - Apollo was a Race: Post-Apollo

"The Conquest of the Moon" was initiated on 18 October 1952 by an article published in *Colliers Magazine* with this title authored by Wernher von Braun, Willy Ley and Fred L. Whipple [1]. This was 40 years ago and much has been accomplished since then. Five years later the first artificial satellite was launched by the USSR, making 1957 the number one year of the space age. Only two years later, the first space probe Lunik 1 passed the Moon at a distance of some 7500 km and became the first man-made object to escape the gravity field of the Earth. This event signalled the race for the Moon.

BY HEINZ-HERMANN KOELLE
Professor Emeritus, Technical University of Berlin

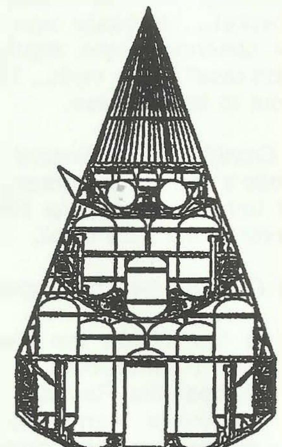
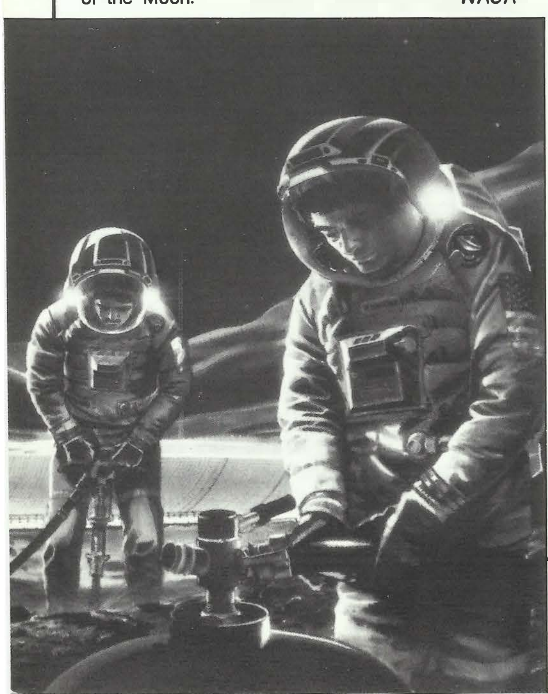


Fig. 1 Heavy lift launch vehicle and lunar cargo shuttle.

The Lead Up to Apollo

The early successes by the Soviet Union challenged the United States of America for space leadership and brought the US Army into the act of conquering the Moon. The US Army possessed the most competent rocket development team in the country headed by Dr von Braun, and recognising that the Moon has neither 'water' nor 'air', it saw a chance to grab a piece of the cake. The Department of the Army, through its Chief for Research and Development, directed by letter, dated 20 March 1959, the Chief of Ordnance to develop plans for the establishment of a lunar outpost by the United States. This study was carried out within three months in a crash effort at Huntsville, Alabama by a team of about 30 people supported by all the technical services of the US Army with the author as the team leader. The study was called Project Horizon and its results were documented in four volumes, later condensed to a summary of 87 pages, and presented to the Secretary of the Army in June 1959 [2]. However, the civilian space agency, NASA, was established and during 1959 it became clear that it would be NASA who would have the mission to conquer space, not the military. Even worse for the Army, the von Braun team would be transferred to NASA. As a result, the Army lost interest in the lunar outpost project.

Astronauts break ground for the installation of a new telescope for an observatory on the far side of the Moon. *NASA*



Meanwhile the Soviet Union achieved the first hard landing on the Moon, Lunik 2 on 13 September 1959, and Lunik 3 took the first pictures of the far side of the Moon on 4 October 1959.

Only three months after the establishment of NASA on 15 December, 1958, its Administrator, Dr Glennan, was briefed for the first time about plans for a manned lunar landing. Dr von Braun, Dr Stuhlinger and the author each gave a presentation in Washington on the subject of launch vehicle development and the use of large boosters. The author predicted that, "perhaps by the spring of 1967, we will have developed a capability of putting ... man on the Moon, and we still hope not to have Russian Customs there!" [3].

During 1959 NASA became acquainted with a potential lunar programme through the activities of the "Goett-Committee". At that time the emphasis was on the feasibility of a manned lunar circumnavigation and recognised that launcher development would determine the schedule and the size of the programme. As a consequence, NASA was eager to have the von Braun team transferred from the Army to NASA. This was accomplished in mid 1960. A status report on the work of the Huntsville team [4] for a manned lunar landing was made available to NASA in February 1960 and sparked the discussions in the direction of a lunar landing. These plans were strongly supported by George Low at NASA Headquarters and Max Faget of the Space Task Group at Langley and led to selecting the name Apollo for the manned lunar programme in July 1960 though, at that time, still envisioning a manned lunar circumnavigation because the Eisenhower Administration was not convinced of the merits of a manned lunar landing. However, the manned mission concept gathered support within NASA and in the Autumn of 1960 three studies were contracted to industry on detailed aspects of a manned lunar landing [3].

Apollo Wins the Race

In January 1961 a NASA committee under the chairmanship of George Low, with the author as one of the members, compiled a report outlining a plan for a lunar programme with the objective of a manned landing. This was submitted to the Administrator on 7 February 1961 shortly after a new President, John F. Kennedy, had taken office and was promising to get the nation moving again.

On 15 February, a new Administrator, James E. Webb, took charge of NASA and was ready to push the space programme forward. While the new President organised his Administration, Yuri Gagarin became the first human being to circumnavigate the Earth on 12 April 1961. This was a shock to the United States and urgent action was needed to restore its standing in world opinion. This desire to be second to none prompted President Kennedy on 25 May, 1961 to announce US plans to "put a man on the Moon and return him safely to Earth before this decade is out". The race to the Moon began.

As documented twenty years later it was indeed a race and was won by the USA [3,5] though a fatal accident on the ground in January 1967, when three astronauts were killed, delayed the programme considerably. After redesign of the manned capsule, the first circumlunar flight took place in

Future
Studies

December 1968 piloted by Frank Borman and his crew and the goal of a manned lunar landing was achieved in July 1969 when Astronauts Armstrong and Aldrin touched down on the Moon to make a short excursion. They returned safely to Earth and to a jubilant nation. The USA, again, was second to none.

The Apollo program came to an end during the last month of 1972. Six lunar missions out of seven attempts had been successfully concluded. Twenty-two billion dollars had been spent in 20,000 companies employing the nearly 400,000 people needed to accomplish the set goal within 11 years.

During the 60s the Vietnam war drained US resources to the extent that the lunar programme had to be curtailed. Production of the Saturn V Moon rocket was stopped and all activities on follow-on programmes eliminated as a new President, Mr Richard Nixon, set other national priorities.

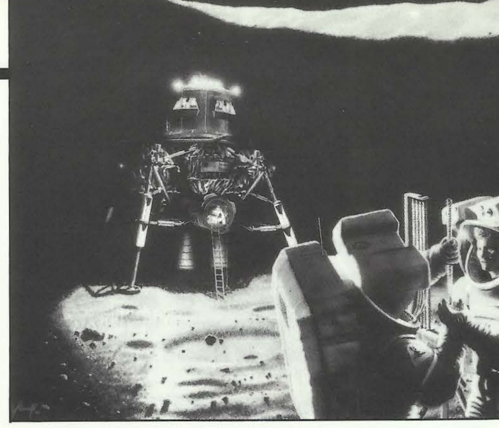
Moon Back on the Agenda

The manned space flight programme of the US was limited to a few orbital flights to Skylab and discontinued in 1975 for six years. The Space Shuttle was the only project left which was relevant to manned space flight. This new launch vehicle enabled the USA, in 1981, to reactivate manned space flight missions but the Moon was beyond reach, almost forgotten by nearly all politicians and by most of the space programme planners.

The one notable exception, however, Krafft A. Ehricke, a prominent space engineer and Fellow of the British Interplanetary Society, who promoted his vision of industrialising the Moon to preserve the environment on Earth. He documented and defended his ideas on developing lunar resources in numerous speeches and publications [6,7].

The year 1982 saw the lunar base discussion rekindled in a major way by a position paper published by a group of leading scientists who got together at Los Alamos to formulate a proposal for a national commitment to establish a manned laboratory on the Moon [8]. Members of the same group, particularly M.B. Duke and W.W. Mendell, organised a lunar base symposium at the National Academy of Sciences in Washington, DC, 29-31 October 1984. This meeting brought together some four hundred interested scientists and engineers from the US and many foreign countries to compile and discuss the available knowledge relevant to lunar development. Numerous papers were published in the proceedings of this symposium, providing a basis of facts and ideas from which new activities could proceed [9]. Many researchers took up the issues and problems of lunar development in subsequent years, leading to a second symposium on the subject sponsored by the Johnson Space Center, Houston in April 1988 [10]. The idea of returning to the Moon had not died completely in countries other than the United States. The Soviets did not abandon the Moon completely even after they lost the race to be the first to send a manned expedition [5].

The International Academy of Astronautics took up the question during the early sixties by proposing a lunar laboratory to follow the manned lunar landing [11,12]. Although this did not materialise and the respective IAA committee was dissolved, the subject remained alive and papers were presented at Congresses of the International Astronautical Federation in 1972 and following years [6]. The 36th Congress at Stockholm sparked a new initiative. This was in 1985 when the author proposed the establishment of a "Return-to-the-Moon" committee by the International Academy of Astronautics.



An Ice Prospecting Lunar Lander Mission. An ice encrusted drill stem is being examined in the frigid, permanently shadowed part of a south polar region crater. *NASA*

'Return-to-the-Moon' Committee

The charter of this committee, approved on 6 December, 1985, stated the following primary objectives:

- ❑ The Committee shall collect, condense, organise and disseminate all relevant Information and the available options for a project leading to a "Return-to-the-Moon" near the turn of this century.

Table 1: Objectives of a programme leading to a permanent lunar base.

(a) Humanistic: A lunar base will

- a-1 assist in reducing tensions and conflicts on Earth thus contributing to peace on Earth
- a-2 provide opportunity for involvement of a broad spectrum of people in exciting frontier activities
- a-3 enhance the evolution of the human culture
- a-4 establish the first extraterrestrial human settlement as an initial step for expanding human activities in the solar system
- a-5 provide a survival shelter for elements of the human race and its civilisation in case of a global catastrophe.

(b) Political: A lunar base will

- b-1 demonstrate the potential growth beyond the limits on Earth
- b-2 provide opportunity for international co-operation
- b-3 provide the infrastructure and experience for global enterprises
- b-4 provide a peaceful outlet for national, competitive high technology urges and a useful employment of existing industrial-military capabilities
- b-5 enhance the national prestige of participating nations

(c) Scientific: A lunar base will

- c-1 improve the understanding and control of our own planet
- c-2 improve our knowledge of the Moon and its resources
- c-3 improve our understanding of the solar system beyond the Earth-Moon system
- c-4 improve our understanding of the universe beyond our own solar system
- c-5 provide a science laboratory in a unique environment for experiments in physics, chemistry, biology, geology, physiology and psychology which cannot be conducted on Earth

(d) Utilitarian: A lunar base will

- d-1 provide rewarding job opportunities and thus stimulate the economy on Earth in general
- d-2 stimulate the development of advanced industrial technology on Earth
- d-3 produce marketable space products other than in the aerospace industry for extraterrestrial as well as for terrestrial use
- d-4 contribute to the supply on Earth with renewable solar energy
- d-5 provide an isolated depository to store high-level, long-lived nuclear and other wastes on the far side of the Moon (if legally possible)
- d-6 provide safe and economical space transportation systems including a lunar spaceport and production facilities (mandatory for the exploration and utilisation of other celestial bodies of the solar system)
- d-7 provide thrust and focus for continued development of space technology other than space transportation systems.

- The Committee shall draft an IAA position paper with the objective to show ways and means on how an international program could be initiated with the goal of establishing a permanent lunar base.

A comprehensive list of the objectives of a lunar base was first developed and is shown in Table 1.

This list of objectives was subjected to a group judgement among the members of the Academy. More than 100 people participated resulting in the following priority list for the five leading objectives:

1. Provide a science laboratory in a unique environment for experiments in physics, chemistry, biology, geology, physiology and sociology which cannot be conducted on Earth.

2. Establish the first extraterrestrial human settlement as an initial step for expanding human activities in the solar system.

3. Improve our knowledge of the Moon and its resources.

4. Provide opportunity for international co-operation.

5. Provide safe and economical space transportation systems including a lunar spaceport and production facilities.

Lunar Manufacturing and Technologies

After trying to find the answer to the *why* of a future lunar base, committee members turned to the *what*. In addition to lunar science, lunar manufacturing was a major item for discussion and analysis, as was the development of a lunar infrastructure such as lunar power, surface transportation, habitats, food production facilities and last, but not least, lunar logistics. The architecture of a typical lunar manufacturing programme are presented in Table 2.

Lunar science and the lunar infrastructure will have priority in the early part of a lunar base programme. In the second phase, however, production of construction materials and simple tools for use on the Moon and experimental production in pilot plants will follow. The analysis produced the list of functions shown in Table 3.

Aside from lunar science and lunar manufacturing, the problems of developing the social infrastructure of a lunar base were also examined. Deliberation made it clear that not all the technologies are available to start a lunar base project. A preliminary list of priority technology items was identified which appears in Table 4.

Table 2: Typical lunar manufacturing programme.

Adapt available technology	1980s-1990s	Earth laboratories	Evaluate available technologies
Lunar global survey	1990s	Lunar orbiter	Establish resource potential, select base location
Automated pilot plants	2000-2005	Automated, self-contained landers	Site inspections, 2-3 processes
Human-tended small plants	2000-2015	Small package plants, habitation, power	Sortie missions for maintenance
Production plants	beyond 2015	Full production plants, hab. extensive power	Delivery of product, full time maintenance crew

Table 3: Extraterrestrial production.

1. *Production of raw materials:*
   - 1-1 Mining of minerals
   - 1-2 Beneficiation of minerals
   - 1-3 Production of raw materials/feedstock
   - 1-4 Production of propellants
   - 1-5 Production of metal products (ingots, sheets, plates, wires, cables...)
   - 1-6 Production of non-metallic raw products (fibres, crystals, solar cells...)
2. *Production/manufacturing of end-products:*
   - 2-1 Production of structural components and elements (bricks, pipes, panels, mats, brackets, beams, radiators...)
   - 2-2 Production of foodstuff (vegetables, meats, water, air...)
   - 2-3 Production of other products for own use (solar panels, filters, tools...)
   - 2-4 Production of other products of export (energy, Helium-3, pharmaceuticals...)
   - 2-5 Assembly operations using produced and imported parts and components
   - 2-6 Services produced for export (maintenance and repair of space vehicles, rent of laboratories, support of external research activities, tourism...)
3. *Direct production support operations:*
   - 3-1 Supervision and control (of manufacturing processes, facilities and equipment including infrastructure)
   - 3-2 Maintenance and repair of facilities and equipment
   - 3-3 Extension of facilities
   - 3-4 Collecting and recycling (of trash and scrap)
   - 3-5 Storage operations
4. *Indirect production support activities:*
   - 4-1 Local transportation (within extraterrestrial complex)
   - 4-2 Power conversion, storage and distribution
   - 4-3 Habitation (life support, housing, recreation, health services...)
   - 4-4 On site training of personnel
   - 4-5 On site research activities in support of own needs (exploration, observation, experimentation)
   - 4-6 On site administrative services (personnel management, financing, planning, legal aspects, public relations...)
   - 4-7 Logistics and space transportation.

Table 4: Technologies for the Moon - from initial bases to self-sufficiency.

System/Technology		Early Base	Mature
Space Transportation			
Earth to orbit - heavy lift vehicles		X	X
Orbital transfer vehicles		X	X
Spaceports:	Earth orbit	X	X
	Lunar orbit	-	X
Low thrust propulsion		-	X
Lunar landers (cargo and human-rated)		X	X
Lunar launch facility		X	X
Lunar Surface Infrastructure			
Nuclear power plant		X	X
Solar energy conversion:	Terrestrially fabricated	X	-
	Lunar fabricated	-	X
Habitation modules:	Modified space station modules	X	-
	Utilising lunar materials	-	X
Lunar Mobility:	Short range, electric rovers	X	X
	Long range, fixed bed	-	X
Construction, mining equipment:	Simple (loaders, cranes, trucks)	X	-
	Complex	-	X
Special Purpose Equipment/Facilities			
Scientific experiments/laboratories:			
	Apollo and space station derivatives	X	-
	Special purpose, utilising indigenous materials	-	X
Materials processing plants:	chemical extraction	X	X
	solar thermal processing	-	X
Manufacturing/fabrication:	simple	X	-
	complex	-	X

Space Transportation Studies

A lunar base cannot be established or operated without a suitable clslunar space transportation system. Its availability, reliability and cost-effectiveness will determine the schedule and the size of a lunar base development programme. Therefore, particular emphasis and care was placed on the problem of lunar logistics. It was of great help that the chairman had particular experience in this field, having been responsible for the preliminary design of the Saturn family of launch vehicles at ABMA and MSFC In the 1957 to 1962 period and also for all planning activities for the Apollo program in 1960-62.

Early in 1987 the International Academy of Astronautics went through a major reorganisation in its committee structure. One result was that the "Ad hoc Return-to-the-Moon" committee became the "Subcommittee on Lunar Development" of the "Committee on International Space Plans and Policies".

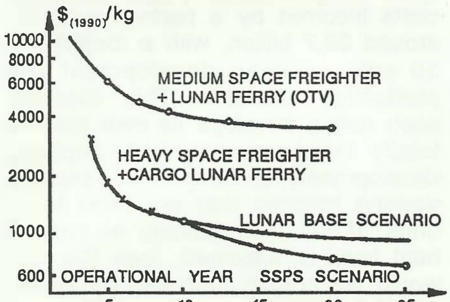
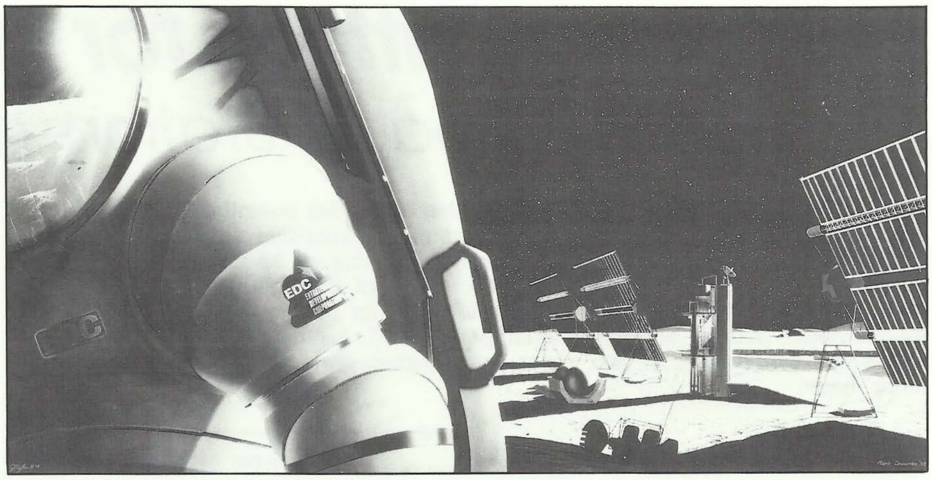


Fig. 2 Projected specific cargo delivery cost Earth - Moon (excluding development cost).

At the end of 1987 the work of the subcommittee had progressed to a point that the draft of the final report could be submitted to the IAA President for publication in *Acta Astronautica* for comments [13]. More than a hundred members of the Academy and interested readers offered critical comments and suggested improvements. These were incorporated in the final report, which also included recommendations on schedules and organisational structures.



The explorer in the foreground is wearing a constant-volume hard space suit with rotating joints and is a representative of a commercial enterprise that intends to develop and exploit extraterrestrial resources. A lunar oxygen production plant, set between the two large solar panels, is generating a supply of rocket fuel that will be used for later journeys to Mars. The lunar base can be seen in the distance. *NASA*

The mission mode recommended is basically the flight profile used in the Apollo mission. While not mandatory in the beginning or in the case of a small outpost only, a refuelling station in low lunar orbit will improve the safety and cost-effectiveness of the operation. For a small lunar base programme a launch vehicle of the Saturn V class would be adequate. With the Energiya such a launch vehicle could be available In the near future [14]. If, however, the launch rate reaches one a month and if a manned Mars project is actively pursued, a launch vehicle of this size will become marginal in terms of operation and cost. A larger reusable launch vehicle will thus be needed in the long run for any ambitious lunar base development programme. The third stage of such a vehicle could also be modified to serve as a lunar shuttle between the lunar surface and the service station in lunar orbit. Vehicles of this type have been studied before, particularly by US companies over the past several decades. The latest studies are those of the Technical University of Berlin, sponsored and supported by the author and producing vehicles and operational data which can be considered as typical for this class of vehicle. Figures 1 to 3 illustrate the vehicle shape and its performance [4,5]. *(See Part 2 of this article, entitled 'Towards an International Lunar Base' to appear in a forthcoming issue of* ***Spaceflight.****)*

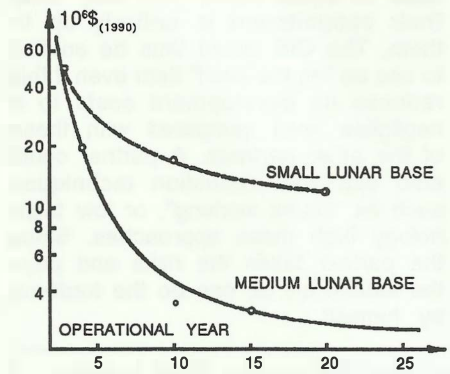


Fig. 3 Projected passenger roundtrip cost Earth - Moon (excluding development cost).

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A New Pattern for International

Part 2 - Space Station and Lunar Base

Access to space at present is too expensive for its full potential to be achieved. It is therefore attractive for the biggest and most expensive space projects to be undertaken internationally so that costs can be shared. So far results have been disappointing. In Part 1, Mark Hempsell attributed this failure to the pattern followed by present large-scale international projects and proposed a new capability-orientated pattern of international partnership. He now looks at the benefits which this would offer to two major astronautical projects, a space station and a lunar base.

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Space Station

Four nations are examining the matter of acquiring a space station capability: CIS, US, Japan and Europe (making the inaccurate, but useful, assumption that Europe can be regarded as a nation for the purposes of this discussion).

The Freedom programme will give the USA a station with a permanent crew of four. The CIS will need to upgrade its Mir station soon and clearly has ambitions to increase its capability over a permanent crew of two, although budgetary limitations may prevent this. Again, a crew of three or four would seem to meet this aspiration. Europe has also been studying its requirement for an autonomous space station under a series of studies called EMSI (European Manned Space Infrastructure). These have concluded that Europe could utilise a four man station. The Japanese have not published any definitive plan for an autonomous station but their requirements are unlikely to be significantly different from the other three potential partners.

Thus there would seem to be four potential customers for a low Earth orbit station with a crew of four and the ability to attach four laboratory modules of about 4-4.5 metres in diameter and weighing around 20 tonnes.

The difference to a nation in being a partner against "going it alone" can be immediately appreciated by comparing a US contribution to the habitation module only with that to the entire Freedom programme. From a massive programme that will dominate NASA's budget for almost two decades the task drops to the almost trivial. Yet the end result in terms of working infrastructure is very similar.

Although partners put in contributions of equal worth, how they meet their commitment is entirely up to them. The CIS would thus be entitled to use an "on the shelf" item even if this reduces its development costs to a negligible level compared with those of the other partners. A partner could also use cost reduction techniques such as "skunk working", or low technology high mass approaches. Since the partner takes the risks and pays the launch bill he can do the trade-off by himself.

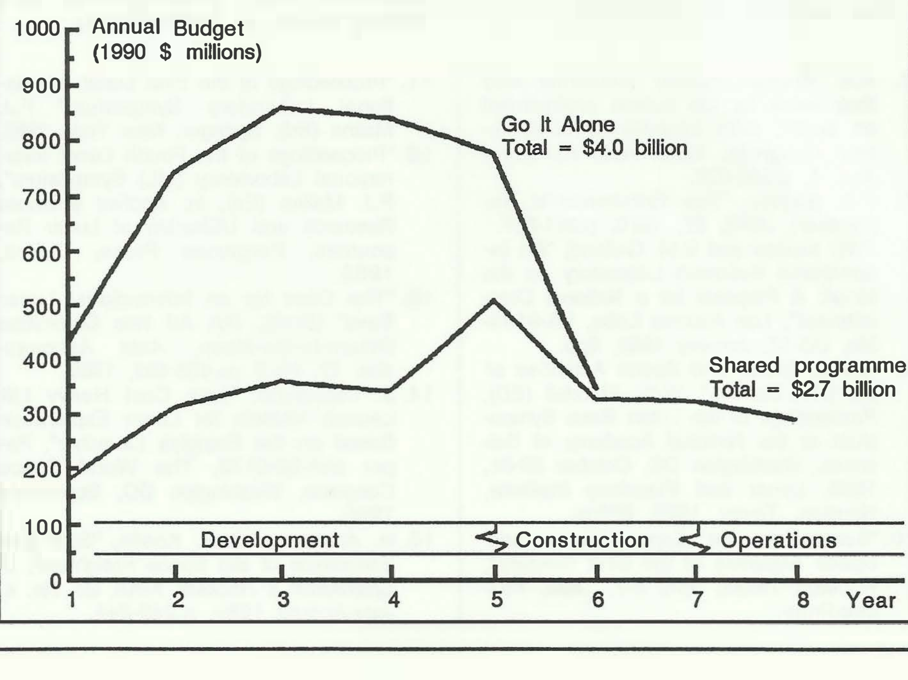
Conversely, if a partner wants to display his technical prowess with a high technology showcase, constructed regardless of cost, that is entirely up to him.

To produce such a station core on its own a nation would have to invest around $4 billion in development and production of flight hardware assuming costing parametrics of a from-scratch design without any special factors (all costs are at 1990 economic conditions). Of this $3.2 billion (80%) is for development. These costs are solely for the core: a working station would require the addition of laboratory modules.

Building four stations with a four way split of development costs would reduce the development and production costs incurred by a partner nation to around $2.7 billion, with a roughly 50/50 split between development and production activities. This assumes each nation develops its own element totally independently, with separate developments of components such as docking hatches that are fitted to all units. If full commonality at component level is assumed, then this cost would fall further; and may be as low as $1.5 billion.

Figure 1 shows these costs spread in a representative manner for both the 'go it alone'. and shared cases. In both cases development is spread over five years and an operational system is ready on year seven, an average figure for partners on the shared programme. Both the reduced overall cost and more even spread of the shared programme are clearly shown.

Figure 1: Space Station Development and Production Cost Profiles



Lunar Base

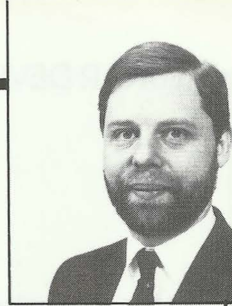
Use of the capability-orientated pattern can have an even more dramatic effect on the acquisition of a Lunar base. A Lunar base needs many elements such as surface rovers and construction equipment as well as the pressurised base itself and hence tends to end up with more independent systems than a space station. This makes splitting up a Lunar base easier than a space station and the potential for maximising the benefits of sharing become greater.

Since no nation has even the beginning of a Lunar surface infrastructure, all would be happy to start with a minimum outpost: the lunar equivalent of Salyut or Skylab. This would consist of a two or three-man facility with around

*Based on a lecture to the British Interplanetary Society in London on June 3, 1992.

Space Collaboration*
Development

Mr Mark Hempsell
BIS Council Member



10 kW of continuous power. It would have a full range of systems to support the likely uses of the base, including construction equipment and a long range pressurised rover. Figure 2 shows budget profiles for the development and production of such a lunar outpost. The same benefits In terms of cost savings and a more even annual expenditure are evident. In this case the savings are greater than on the space station because of the more natural splitting of the various elements.

The outpost itself is much smaller than current NASA thinking, as exemplified by the 90 day study conducted in 1989. However, with the construction of four or five such outposts with a permanent presence of between eight and 10 people, the overall infrastructure is larger. The spread of bases allows much more of the Lunar surface to be directly explorable from bases. The four or five bases in total should cover an area the size of southern England. The bases can also act as supports for each other both for safety and for experiments, such as interferometry, that require long baselines. So not only is the infrastructure larger and safer but Is also more suited to the task of scientific exploitation.

Conclusions

In the two cases examined the use of a more suitable pattern of international collaboration would seem to reduce the total acquisition costs significantly and spread those costs more evenly. Table 1 illustrates this with sharing, with going it alone, and with some existing European projects. One must bear in mind these costs do not include launch and transport system development and that Hermes and Columbus have proved too expensive to carry through. So on a go it alone basis the acquisition of a space station or Lunar base is highly problematic.

By contrast the shared cost, of between 50% and 70% of the go it alone cost, takes the acquisition cost well below that of programmes which Europe has already decided it can afford. Therefore, for Europe and probably the CIS and Japan, the new pattern of international collaboration outlined is probably the only practical route to obtaining autonomous space stations and Lunar bases.

There are other advantages to the capability collaboration pattern in addition to the cost benefits. These include the full autonomy each nation will enjoy, a significant reduction in the impact on the launch systems, and the mutual support from other partner's systems which improves resilience and safety.

There are also advantages when the overall picture is examined. Although the permanent facilities will tend to be smaller, because more nations are operating them, the overall infrastructure tends to be bigger and grow much quicker. Mankind moves out into space faster and In a more secure manner.

Although the two examples given are both fixed infrastructure elements there is no reason to believe the capability pattern will not work on transport elements, with similar benefits.

It is concluded that, from the point of view of acquiring space capability, there are no disadvantages to this proposed approach to international collaboration. From the technology point of view the proportion of money that goes into the design and research activity (as opposed to production) drops from around 80% to around 50%. From the viewpoint of national prestige, every nation's facilities look roughly the same reducing its prestige value. So long as technology and prestige issues are mixed with the basic infrastructure goal of acquiring capability it is unlikely that more appropriate patterns of international collaboration will be used.

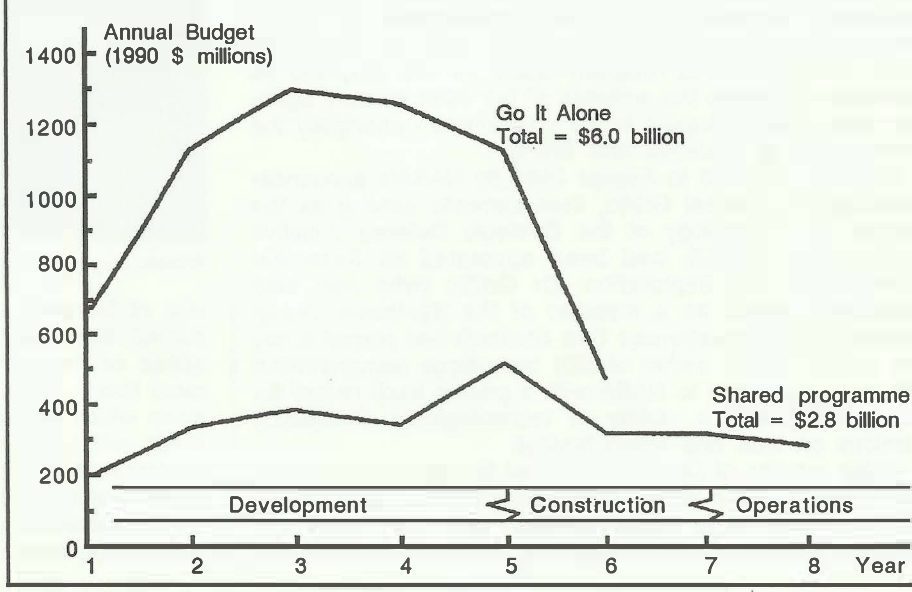
Indeed, the argument can be taken further. The confusion over technology and prestige identified in Part 1 can be shown to lead to inappropriate requirement generation, inappropriate project management, inappropriate system architecture and inappropriate technology selection. When the effects of all these are combined, it is possible that infrastructures costs are an order of magnitude higher than they would have been if improving space capability had been the sole objective.

Given the pitiful state of the western world space infrastructure and the embarrassing collapse, even effective cancellation of so many international projects, the time has now come to look again at the fundamental reasons for going into space. With a clearer vision, and a single-minded approach to meeting that vision, it is possible that we may be able to break out of the current malaise and recover the momentum of an outward drive into space. The appropriate forms of international collaboration can help by offering the advantages of sharing, while enabling each nation to follow an autonomous path in the development of its own infrastructure.

Table 1 Cost Comparisons for European Programmes

		US$ billion
Shared		
	Station Core	2.7
	Lunar Base	2.8
Solo		
	Station Core	4.0
	Lunar Base	6.0
Planned		
	Hermes	7.7
	Columbus	5.2
	Ariane 5	4.3

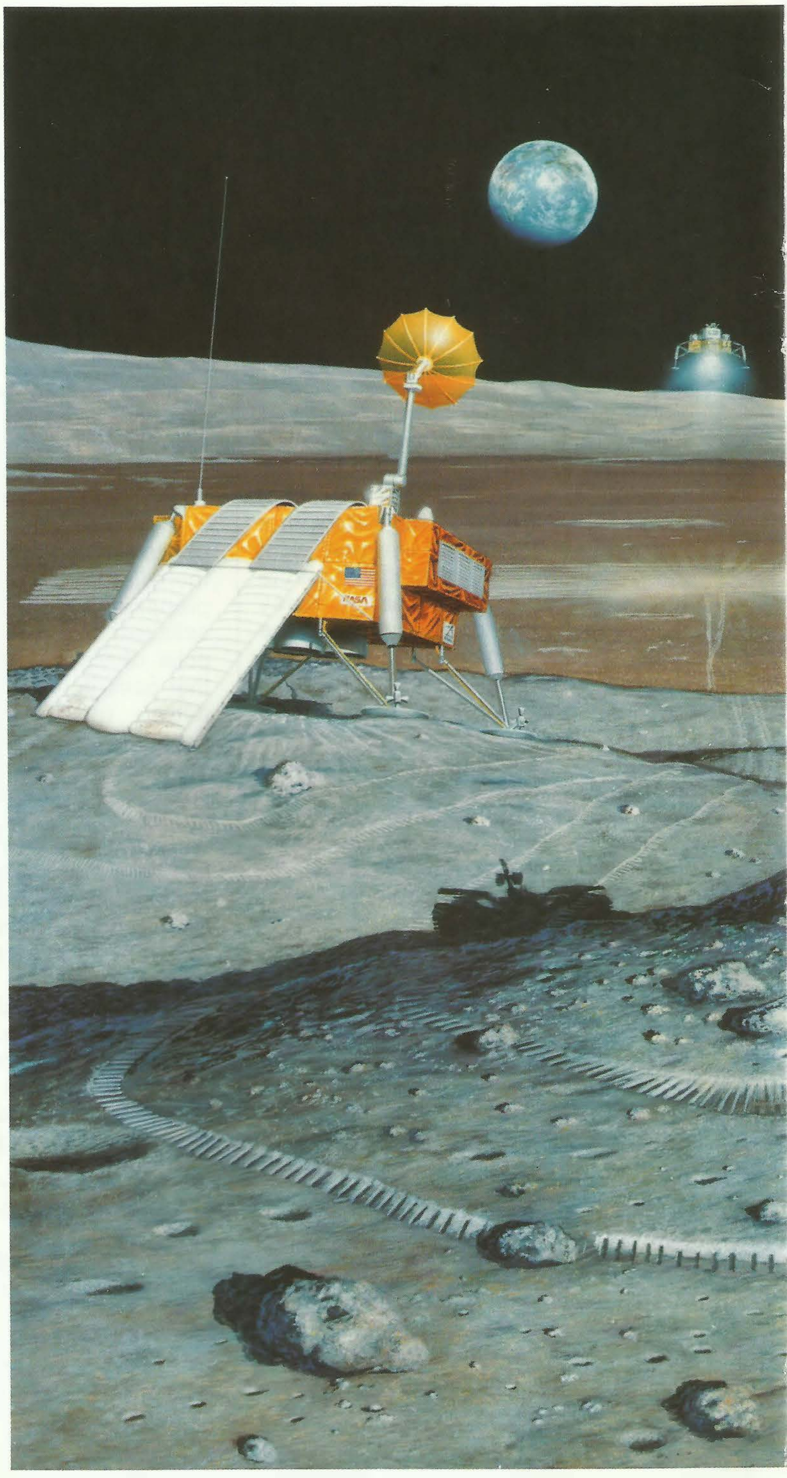
Figure 2: Lunar Base Development and Production Cost Profiles



Back to the Moon with

Low-Cost Lunar Missions to Spearhead the US Spac

A team of engineers at NASA's Johnson Space Center (JSC) - the Center whose name has been synonymous with human space missions for the past thirty years - has begun work on a robotic lunar lander called Artemis, which it plans to send to the Moon in the mid 1990s. However, any aspiring astronauts who might now be worried that JSC is about to turn its back on human space missions have no cause for concern. In fact quite the opposite is true, for Artemis is one of several low-cost lunar probes which NASA and JSC are currently studying as a means of making an early start on America's Space Exploration Initiative (SEI) - an ambitious programme which encompasses plans to send astronauts back to the Moon and then onwards to Mars.



Artemis common lunar lander and surface rover payload.

Getting Started

The SEI was announced with much fanfare by US President George Bush in July 1989 during celebrations to mark the twentieth anniversary of the Apollo 11 lunar landing. Although President Bush continued to support the SEI right up to the time he left office this January, only limited progress has been achieved in the past three years. The programme has still to win the support of Congress, which has exercised its right to veto the Bush Administration's spending proposals. At the heart of their objections lies the likely cost of such ambitious plans, the total cost of which have been typically estimated at around $500-billion to be spent over a thirty year period.

The lacklustre response was such that by late 1990 many observers were suggesting that the SEI was an idea whose time had not yet arrived, and questioned President Bush's judgement in making such an announcement at a time when NASA was (and remains) hard pressed to complete many of its existing programmes. However, NASA has since taken several steps to elevate the standing of the SEI within the agency, and in so doing has demonstrated that Moon-Mars exploration has now become an integral plank of its long-term future.

The first such step came in December 1990 when an independent Office of Exploration was re-created at NASA Headquarters after an absence of almost a year. This was a key recommendation of the Advisory Committee on the Future of the US Space Program, a blue ribbon panel headed by Martin Marietta Chairman Norman Augustine, which convened in the summer of 1990 to consider the long-term future of the civilian space programme. Besides giving the exploration programme high level representation at NASA Headquarters, the Office of Exploration will also eventually serve as the National Program Office for the SEI, and as such will coordinate the activities of the other Federal agencies which will participate in the programme - principally the Departments of Defense and Energy.

This was followed in August 1991 by NASA's announcement that Dr Michael Griffin, then currently serving as the Deputy for Technology at the Strategic Defense Initiative Organization (SDIO), had been appointed as Associate Administrator for Exploration. Dr Griffin (who had also previously served as a member of the Synthesis Group chaired by former astronaut Tom Stafford) had played a key role in the "Delta" series of SDI technology demonstration missions, and came to NASA with a proven track record for having completed a variety of technologically demanding missions on time and within budget.

Within months of Dr Griffin's arrival the Office of Exploration had announced plans to shift away from an interminable series of long-range paper studies which had previously characterised the SEI, by beginning development of a series of low-cost lunar precursor missions. The philosophy behind this move was to provide the programme with a series of near-term milestones and push aggressively to meet them. Although modest compared to the human missions which will follow, the rapid accomplishment of these goals will provide the programme with positive signs of progress and help build confidence in anticipation of the more ambitious human missions which will follow. The robotic missions will also provide important scientific and engineering data which can be factored in to the design of

Robots?

e Exploration Initiative

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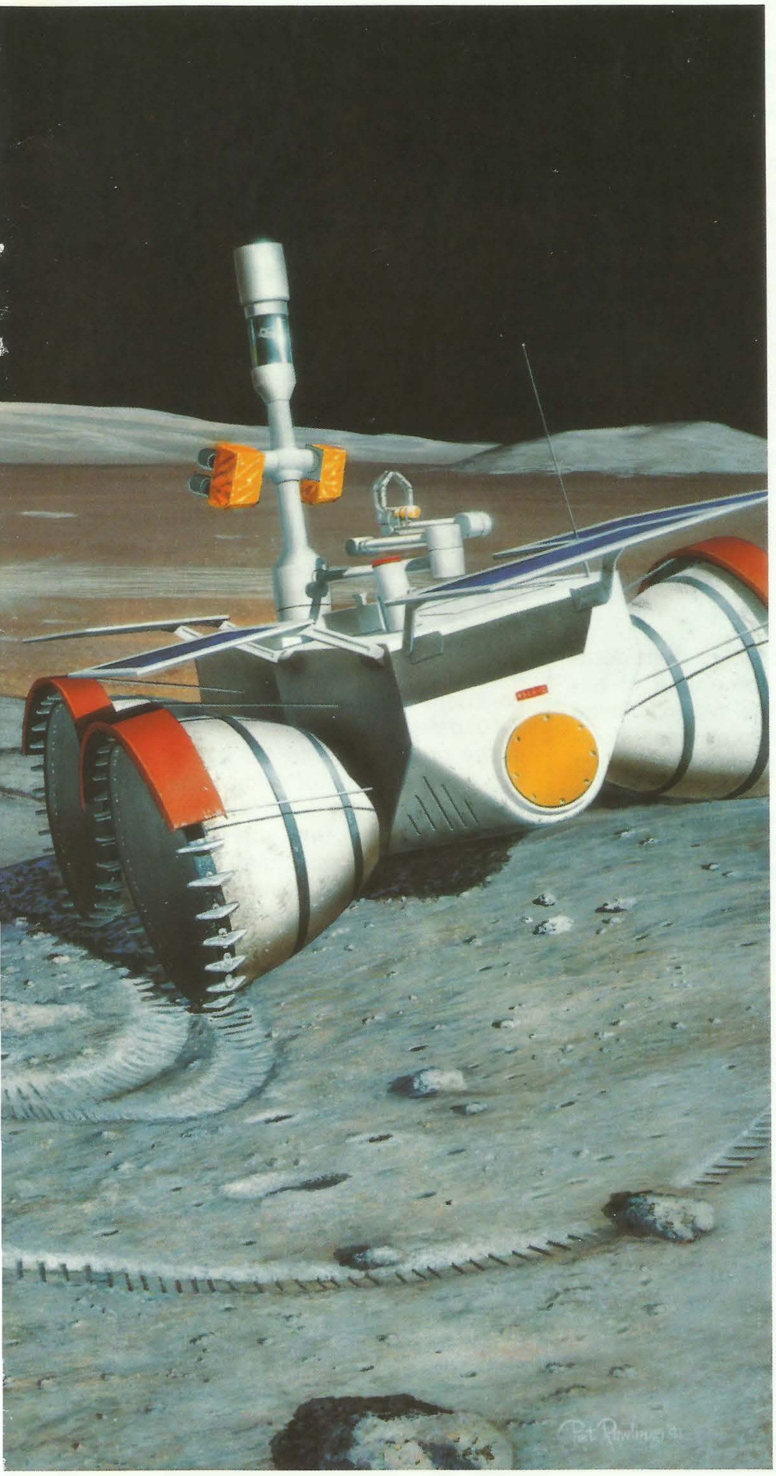


Pat Rawlings/JSC

human Moon-Mars vehicles at an earlier date than had previously been thought possible - thereby decreasing the cost and risk of the overall exploration programme.

The robotic lunar missions represent the first phase in a five part strategy designed to culminate in the first American astronauts reaching Mars early in the next century. However, despite having recently announced proposals for early human lunar missions at the Annual Meeting of the Association of Space Explorers, officials in charge of the exploration programme stress that no firm deadlines have yet been set for its later stages. The programme is now structured so that it can be adapted to changing circumstances and available funds, an approach which has been dubbed "go as you pay".

The SEI precursor missions have also been placed under the spotlight as a test of NASA's efforts to try out several new innovative management cultures. It is hoped that these new approaches will lead to missions being completed on shorter schedules and at much lower costs than is traditionally the case. The new measures range from making greater use of Federal facilities for developing and building flight hardware (as was the case during NASA's early years), to giving industrial contractors greater autonomy, thereby avoiding the pitfalls of inappropriate government "micromanagement" [1].

The Lunar Scout Project

The initial series of precursor missions now under discussion comprises of two Lunar Scout polar orbiters and one Artemis lunar lander, all of which are to be launched in the 1996/97 timeframe. To allow for launches aboard Delta II medium-lift launch vehicles, each spacecraft will be limited to a fully fuelled mass of about 1,300 kg and will carry highly focused scientific payloads consisting of no more than two or three instruments. The total cost of each Lunar Scout flight is estimated at about $100-150 million, whereas the more complex Artemis will cost slightly more.

The two Lunar Scout orbital spacecraft will be identical in all respects apart from their instrument payloads. Under present schedules the first Lunar Scout should be launched in March 1996, followed 12 months later by the launch of Lunar Scout II.

The payload selected for the Lunar Scout I mission comprises an X-ray spectrometer to estimate the abundances of six major rock forming elements; a neutron spectrometer to detect the presence of volatiles; and a High Resolution Stereo Camera to provide global photographic coverage. In the case of the latter, NASA has held negotiations with the German Aerospace Research Establishment (DLR) regarding the possibility of using a slightly modified version of the imaging system which Germany is providing for Russia's Mars '94 mission. The instruments manifested for the second Lunar Scout are an imaging spectrometer for mineralogical surveying; and a gamma ray spectrometer to map the elemental composition of the lunar regolith. From their respective polar orbits, both spacecraft will also operate in tandem in order to map the subtle intricacies of the Moon's gravity field.

Collectively, these instruments will provide much of the cartographic database required to support human exploration activities and will provide data pertinent to the utilisation of lunar resources for habitat construction. The data will also initiate a new phase in lunar science, and should help scientists better understand the nature of the Moon's origin and its subsequent evolution [2].

In view of the tight 31-month development schedule, the Lunar Scout Program Office at JSC has wasted little time in bringing scientists into the team at the earliest possible opportunity. Selection of the various instruments and their principal investigators took place in June 1992. The scientists will be assisted in their preparations by the Applied Physics Laboratory - a research division of the Johns Hopkins University based in Laurel, Maryland - to which JSC has given overall responsibility for payload integration and mission planning.

On the engineering side, Boeing and Martin-Marietta were selected to study the provision of flight proven space-

craft which can be easily adapted for the lunar missions. NASA's eventual aim is to issue contracts for the "commercial buy" of the spacecraft, however, this process has not progressed any further due to a lack of funds.

The Artemis Project

Whilst the objectives of the orbital missions were able to draw on over twenty years of planning for an advanced polar orbiting spacecraft (Lunar Observer and its predecessors), many scientists admit that JSC's proposal to resume surface exploration at such an early data caught them by surprise, and consequently the objectives of surface missions are just not as well defined.

The potential significance of the Artemis project reaches far beyond the scientific and engineering data that will be returned during the course of its missions. It is twenty years since the last Apollo astronauts returned home from the Moon, and over fifteen years since NASA launched a spacecraft designed to land on a planetary surface (the Viking 1 and 2 spacecraft which landed on Mars in 1976). In the time that has since elapsed many of the engineers behind these missions have long since retired or moved on to other areas of activity. The Artemis project is, therefore, the first step towards re-establishing the expertise needed to conduct human missions beyond low Earth orbit, and will serve to bring on the next generation of engineers who are likely to be responsible for guiding the SEI through its most critical stages. It is no accident, therefore, that JSC should now be directly promoting a scheme for a robotic lunar lander, for such activities may provide the key which unlocks the Center's long-term future. The choice of the name Artemis is no accident either, for according to Greek mythology Artemis was the Goddess of the Moon and the twin sister of Apollo.

Work on the Artemis Common Lunar Lander (CLL) began in the summer of 1991 when a workshop was held to determine the level of interest in a vehicle which could deliver approximately 200 kg to the lunar surface. The CLL comprises a simple non-reusable platform on which a variety of payloads can be mounted. To keep development costs down to the absolute minimum, extensive use will be made wherever possible of existing off the shelf hardware [3].

A typical Artemis mission would begin with a launch from Cape Canaveral, Florida, aboard a McDonnell Douglas Delta II. The spacecraft would then complete a five day translunar coast before arriving in a lunar parking orbit, from which It would be able to reach any part of the Moon's surface. For most payloads it has been assumed that the actual landing would be timed to coincide with the lunar dawn so that operations could be conducted for at least the full period of one lunar day (equivalent to fourteen Earth days). The CLL itself is required to operate for no more than an hour on the lunar surface, since it is intended that each payload will be self-contained and will therefore carry its own independent power and communications systems.

Payloads Planned

The payloads now under consideration encompass the full gamut of activities possible on the Moon. These include rovers to perform mineralogical and geological prospecting; pilot production plants to demonstrate the feasibility of extracting oxygen and other useful materials from the lunar soil; telescopes to assess the benefits of building astronomical observatories on the Moon; and experiments to test the practicality of beaming electrical power back to Earth.

The first Artemis mission had been planned as an in-house affair at JSC, but owing to the heavy workload as the deployment of Space Station Freedom begins, this work will now be contracted to industry. Since it will be only an initial test flight, the payload for this flight will be limited to just 120 kg. In spite of this constraint, it is possible that this mission could carry two small mini-rovers; similar to those which have emerged in the past few years as part of on-going development projects at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California [4]. That two such rovers can be accommodated within such a small payload envelope is a sign of the progress made in recent years in the miniaturisation of electrical components, a fact which underpins the current trend towards microspacecraft.

If this plan is adopted, the two rovers will be built to identical specifications, thereby providing some redundancy should one of the vehicles become incapacitated. The primary objective of a rover mission would be to conduct a one-time exploration of a scientifically interesting or operationally challenging site, or the detailed reconnaissance of a potential lunar outpost site. The recommended payload for each rover comprises an alpha-proton backscatter spectrometer to provide information on the chemical composition of lunar soils; a Mossbauer backscatter spectrometer to provide high quality mineralogical data; and stereo cameras to provide high resolution images of the lunar surface. The solar powered rovers are designed to operate for a minimum of 3 lunar days, but JPL is reasonably confident that this can be extended to 7-10 days. Traverse speeds would be in the order of 0.5 to 1.0 km/hr, allowing several tens of kilometres to be covered during the mission.

Alternatively, the scientific objectives might be better met by a single, more sophisticated rover taking up the full 120 kg payload. Not only would this allow greater margins to be employed in the rover design, it would also allow a much wider variety of scientific instruments to be carried. With estimated operating speeds of 5 km/hr, a larger rover might be able to cover several hundred kilometres during a single lunar day.

One of the many potential sites being considered for the first Artemis mission is the Hadley-Apennine region, which was the landing site for Apollo 15 back in 1971. In a proposal somewhat reminiscent of Apollo 12's visit to the landing site of the Surveyor 3 spacecraft, it has been suggested that one of the Artemis rovers could approach the abandoned Apollo 15 hardware to assess the effects of long-term exposure to the lunar environment [5].

For later missions of the CLL the payload will be gradually increased up to its operational value of 200 kg. Current plans call for an average of two missions per year, and there is every probability that these Artemis missions will overlap with the initial flights of any ensuing human exploration programme. "Infrastructure" payloads which are under consideration for this phase of the programme include communications equipment and

CORRESPONDENCE

Mir Lunar Orbiter?

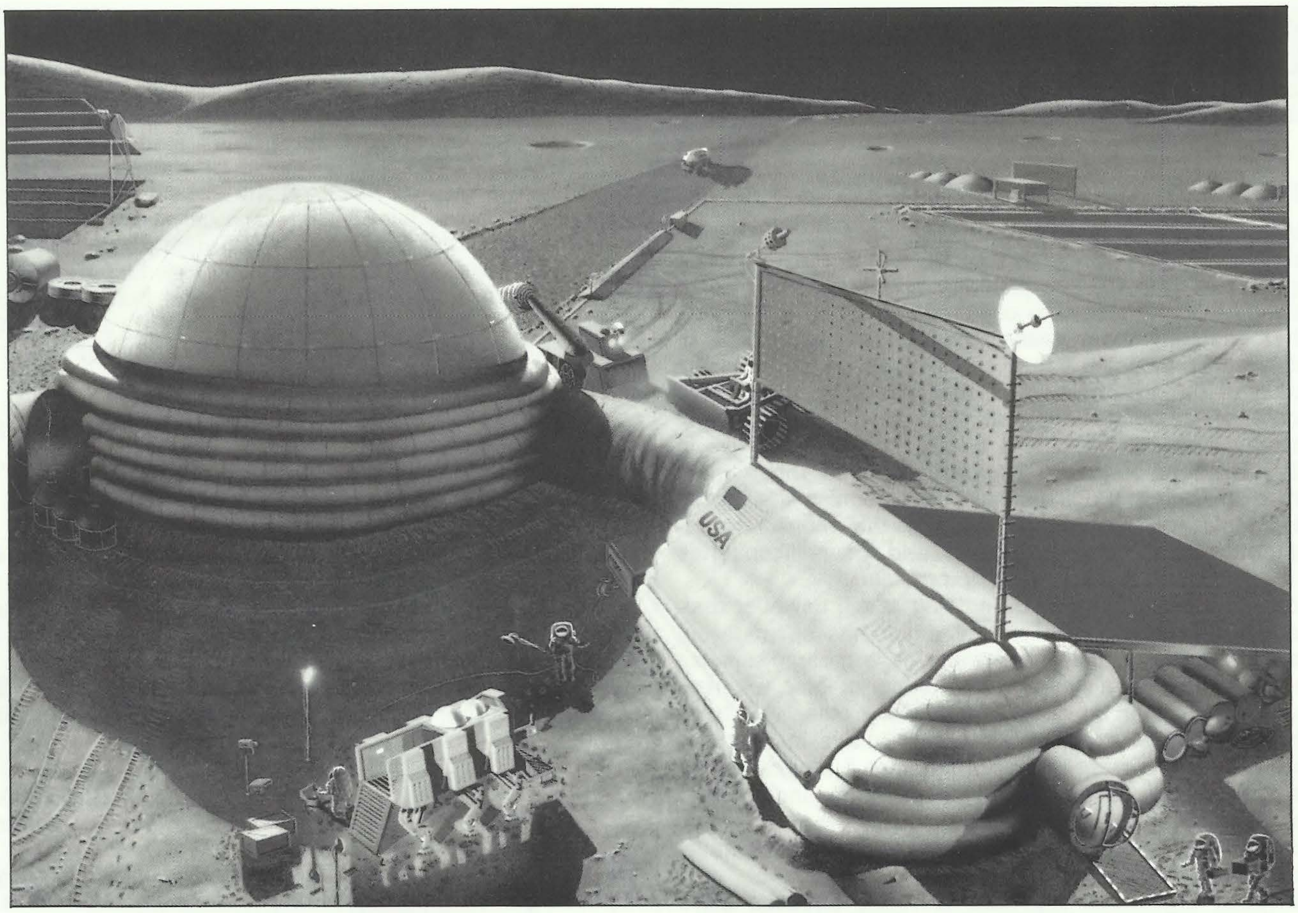
Sir, May I make a suggestion that when the present Mir space station is no longer required by CIS that it be boosted into a lunar orbit - to act as a manned lunar observation post? The increased cooperation between CIS with both USA and European space agencies would lend itself admirably to this project. The USA could provide SSME units and a small propellant tank to act as propulsion devices to boost Mir to the lunar altitude required. The CIS could provide modified Soyuz TM craft (à la Zond?) to act as ferry craft to and from the lunar orbiting Mir station with ESA providing additional observational platforms (à la Eureca or polar platform) for a 3-5 year programme?

I envisage that crew stay-times at the lunar Mir observation platform would be between 3-6 months with a crew complement of 3 persons. This would require about 10 Soyuz ferry craft and, maybe, 5-6 Progress supply flights.

An alternative mission would be a 'looping-eight' orbit around the Moon and the Earth. The Earth loop would be close enough and long enough to allow the Shuttle and Soyuz-TM craft to dock and exchange crews and materials.

I would be interested to learn of other readers views and reactions.

PHILL PARKER, FBIS, Staffs, UK



Lunar Outpost: Establishment of a permanently inhabited lunar outpost is a crucial step toward expanding human presence into the solar system. The outpost could expand into a network of lunar bases and ultimately a lunar settlement. *NASA*

beacons which could help guide astronaut crews to a safe landing on the lunar surface.

Current Status

Artemis and the two orbiter missions are just proposals at the moment, and will remain so unless the money can be found to carry them through to completion. As part of Its Fiscal Year 1993 (FY-93) Budget submission, NASA sought $29 million to formally begin work on these missions. It had been hoped that the establishment of the Office of Exploration and the appointment of Dr Griffin as its director would have generated enough momentum to carry these projects through the approval process for a new start. However, the past twelve months have not fostered an environment in which new ideas can prosper. The uncertainty of election year, the deepening recession in the US economy, and even the controversy which surrounded Richard Truly's resignation as NASA Chief Administrator have all contrived to thwart any hopes which NASA may have had of making an immediate start on the SEI precursor missions, and both the House and Senate budget committees acted during the summer to strike funds for the missions from NASA's FY-93 budget.

Having been chided by Congress in the past for its unwillingness to adopt the new procurement and management practices embodied in the Office of Exploration's approach, the lack of support for the robotic lunar missions has come as a severe disappointment to NASA's new management team, headed by Chief Administrator Daniel Goldin. With no money in the FY-93 budget to sustain these activities, work on the precursor missions is presently frozen. However, the space agency is rallying behind efforts to have funds included as part of the FY-94 budget. With the Democrats having taken control of the White House under the leadership of Governor Bill Clinton, NASA may face even more of an uphill struggle in its battle for FY-94 funds. The SEI has always been viewed as President Bush's own personal vision, and as President Clinton and Vice President Al Gore take office, there have been few signs to suggest that the exploration programme will continue to enjoy strong support from within the Oval Office. With a new President, widespread changes in Congress, and yet even more changes at NASA Headquarters on the cards, predictions are hard to make, but this year could well be the make or break year as far as the immediate future of the SEI is concerned. As the twentieth anniversary of the Apollo 17 mission passes, the fate of the SEI lunar precursor missions could well determine how much longer astronauts Eugene Cernan and Jack Schmitt will hold on to their title of having been "the last humans to have walked upon the Moon's surface".

Acknowledgements

The author wishes to thank Stephen Bailey, Artemis Project Manager, JSC, and Dr Paul Spudis, of the Lunar and Planetary Institute, Houston, for assistance kindly provided during the preparation of this article.

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Correspondence

Space Plan for Human Survival

Sir, Many lessons of history are disregarded but one which remains essential is an ability to withstand dramatic changes. This requires pre-planning and the setting up of an adequate Infrastructure to cope with all kinds of hazards, whether resulting from some local maladministration or disaster, or from matters that affect all of us such as the depletion of the ozone layer or the Impact by a fair-sized meteorite or cometary nucleus.

Whichever way one looks at it, our greatest hope lies In the development of space exploration. Even those most absorbed in Earthly problems have to recognise that space developments will increasingly provide the monitoring requlrements, technical "know-how" and new discoveries most likely to solve these Earthly problems.

Those who really want to do nothing at all, however realistic and sound-based their current arguments seem to be, concentrate solely on the present and do a gross disservice to the human race as a whole which, sooner or later, will have no option other than to go out to explore other worlds or perish. Whether we prepare ourselves for this in a proper manner and at the proper time, or whether it results from a last-minute scratch job as a result of some impending crisis yet to come, depends on decisions taken now.

The question which faces us Is not whether space travel will or will not develop but when.

Anti-space arguments are hard to refute because there are always so many other things which need attention and we are told that we should 'concentrate more on making a better world for the Moon to revolve round, rather than exploring the Moon itself'.

In reality, the fallacy is all the more sinister because It obscures the truth. Going to the Moon is only the first step on a road to make our own world better, rather than the reverse. It is a mistake to think of lunar exploration as an end in itself. Space exploration is part of the process of accumulating knowledge, technical ability and scientific data which will enable us to survive Into the distant future.

P.R. FRESHWATER
Oxon, UK

The British Way

Sir, One interesting offshoot from John Allison's letter (***Spaceflight***, December 1992) Is that according to a recent Japanese technology report 72% of useful post-World War II inventions were British and 10 to 12% were USA.

The latest British invention being donated free (i.e. no patents being taken out) to the world, involves diamond material being sprayed onto surfaces to make them very hard. One use could be in car engines - this will obviously make them last longer and probably have some effect on the price of petrol. This and other uses could have a profound effect on everyday life, including jobs.

In a recent Saturday review article (*The Times*, November 28 1992) on the Channel Tunnel Project, Sir Alastair Morton believes our problem lies in Treasury funding (accountants run projects) so new projects never get funding because of the risks involved. The French, In the same article, believe that we never start with a plan (because we are not allowed one?) but we always managed to sort something out in the end, such as the Lancaster which was needed in a hurry.

JOHN C. FAIRWEATHER
Surrey, UK

Man-Hours in Space

Sir, Whilst recently updating my files I came across the following fact:

> At around 8 pm GMT on 27 May 1992, the Soviet Union/CIS surpassed the 200,000 man hours mark in accumulated space flight. This was achieved by Kaleri and Viktorenko onboard Soyuz TM-14/Mir. At the same time the Americans had just passed the 60,000 man hours mark.

It had taken the Soviet Unlon/CIS over 25 years (12 April 1961 - 26 May 1986) to accumulate their first 100,000 man hours In space, (achieved by Klzlm and Solovyov onboard Soyuz T-15/Salyut 7 at around 9 pm GMT on 26 May 1986), but In comparison it had only taken them 6 years and 1 day to complete their second 100,000 man hours.

TIMOTHY K. BINNS, FBIS
Kent, UK

Spaceflight Magazine

Sir, I would like to compliment the British Interplanetary Society on your excellent magazine ***Spaceflight*** and your efforts in general to keep space activities that will benefit mankind in the public eye, particularly Space Shuttle missions, Soviet activities on board the Mir space station, and the many applications for which satellites are utilised (remote sensing, astronomy, planetary exploration and so on....).

B. BORRADALE
Australia

Sir, Thank you very much for sending me my copy of ***Spaceflight*** so promptly in response to my letter. It is excellent.

Emigrants (1948 in our case) do not lose interest in the Old Country's performance in many spheres. The work you do Is Important not only for aerospace education and effort, but also for the English language.

Thank you again for ***Spaceflight***.

DR GUY RICHARDS
British Columbia, Canada

Sir, My experience of the Society began under the distinguished Presidency of Arthur Clarke with whom I continued correspondence until his departure for Sri Lanka.

I shall be very glad to be Informed of the origin of this vital and imaginative body - and congratulate all concerned with the production of ***Spaceflight***. The best magazine of its kind.

PATRICK HORSBRUGH, FBIS
Indiana, USA

Ed: *The Society's Brochure gives details of some of the Society's History and Activities. A book is also in preparation on the History of the Society.*

SETI: Low Rating for Planet Earth

Sir, With regard to the SETI experiments (***Spaceflight***, January 1993, pp.6-7), it seems to me that those so engaged would be well advised to devise a binary message to be Interpreted, quite unequivocally - These animals are Immature and dangerous. Keep clear for at least another 200 solar orbits of this planet (and even that may well be unduly optimlstlc!).

By the same token, any Incoming message might be expected to read, succinctly, Wake up and grow up! Till then, stew in your own juice!

JOHN ALLISON
West Midlands, UK

Soviet Mars Mission Attempts

Sir, A new publication on the planet Mars [1] has brought to light new, definitive information on Soviet launch attempts to the planet - laying to rest old speculations, as well as raising new questions. A table follows which lists Soviet-related attempts to send planetary missions to Mars from 1960.

Chronology of Mars Mission Attempts [1].

	Name	Launch Date	Result
1960	None	Oct 14	Failed to reach orbit
1962	None	Oct 24	Failed to leave orbit
	Mars 1	Nov 1	Passed Mars June 1963; telemetry failed
	None	Nov 4	Failed to leave orbit
1964	Zond 2	Nov 30	Contact lost after 5 months
1965	Zond 3	Jul 18	Photographed Moon; went to Mars orbit
1969	None	Mar 27	Failed to reach orbit
	None	Apr 14	Failed to reach orbit
1971	Kosmos 419	May 10	Failed to leave orbit
	Mars 2	May 19	Orbited Mars; descent module crashed
	Mars 3	May 28	Orbited Mars; descent module landed; transmitter failed
1973	Mars 4	Jul 21	Failed to orbit Mars
	Mars 5	Jul 25	Orbited Mars; partially successful mission
	Mars 6	Aug 5	Flyby; descent module landed on Mars; very little data
	Mars 7	Aug 9	Flyby; descent module missed the planet

The new information indicates that only one launch attempt to Mars took place in the year 1960, on October 14. This means that information supplied in September 1962 to the US Congress by the then NASA administrator James Webb that a Mars attempt took place as well on October 10 of that year (1960) is incorrect [2,3]. (What the October 10 launch was connected with is open to speculation.)

The 1960 mission involved a spacecraft similar to Venera 1 (launched February 1961) which weighed about 640 kilogrammes. Its 10 kg scientific payload included a magnetometer, ion traps for measuring solar plasma, cosmic-ray counters and micrometeroid sensors. The October 1960 mission contained no camera, contrary to American speculation.

In 1964, two space missions were planned to be sent to the vicinity of Mars, but the latter Zond 3 was not able to be launched in time to meet the Mars launch window, so instead was launched to the vicinity of Mars' orbit. It appears that both Zond 2 and Zond 3 were to complement each other's scientific measurements, while only Zond 3 carried a camera planned to take pictures of the Martian surface.

The new information confirms American reportage of two launch failures in 1969, one on March 27 and the other on April 14. Both were due to failures of the Proton rocket in the ascent phase. The objective of these two missions was to send spacecraft into Martian orbit, but no landers were prepared for these two launch attempts.

Recently, there have been reports that the 1971 missions (Mars 2 and Mars 3) had landed two rovers on the Martian surface, but were unable to operate because of the failure of other spacecraft systems during the landing phase [4,5]. The new information does not support these speculations. The landing capsules were intended to make measurements of the temperature, pressure, wind velocity, and atmospheric composition, measure the chemical and physical properties of the surface material, and look for organic compounds. Correspondence from a colleague connected with the space flight establishment in Russia reads, "I know nothing about these rovers. I think that this is the invention of journalists, of which there are many such things in the Western and Russian press" [6].

Kosmos 419 was intended to become the first satellite of Mars, consisting of an orbiter only. Its resulting weight reduction would have allowed it to fly a faster trajectory ahead of the two American Mariner spacecraft. As has been reported in ***Spaceflight*** [7] the spacecraft's computer was sent an incorrect firing timing sequence, dooming the mission to Earth orbit and quick decay.

PETER PESAVENTO
California, USA

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SETI: Binary Message Search a Waste of Time

Sir, Current searches are based on the assumption that messages to and from extra-terrestrials would be expressed in a digital form as a binary code thus necessitating an electromagnetic carrier wave with transmission speed limited to the velocity of light. Thus message transmission times except within the solar system and to the nearest stars are too long for practical message interchange, and transmission source frequencies must be confined to zones where natural electromagnetic radiators such as stars are largely silent. Therefore it is argued we must begin our searches by simply looking for such binary coded messages among these zones. But I would claim we are wasting our time, because the assumption is invalid on several counts.

Firstly any extra-terrestrial looking for others would have reached a critical point in its scientific evolution where the nature of information as it applies to the internal structure of the Universe and to life was well known [1,2]. This is not the case yet on Earth. For example biological brains do not utilise information in binary form and for good reason. Information in the form of 0s and 1s cannot efficiently reflect the spacio-temporal nature of reality which all brains must do if they are to be able to survive in the process of natural selection which, there is no reason to believe, does not apply to extra-terrestrial life. For this reason, I postulate that brains, analogue devices and superbly efficient simulators and modellers of reality employ quite a different information processing paradigm. This [3,4] exploits the known processes of holography and analogous wavefield phenomena such as holophony, providing a wavefield model of analogue

computation. This model of computation, common to all types of wavefield, is based on the mathematical formalisation of the generalisation of Huygens' Principle for the propagation of wavefronts in a non-linear medium [5].

The non-linear medium specifies the morphology of the computer or brain so that the propagation of wavefronts are the signals required to control the brain so that it can perceive and cognize. In this model the nature of information and the processes of perception and cognition are well defined, and can be validated for human brains by means of simple experiments, as shown below. *Thus, if extra-terrestrials were transmitting information based on their understanding of its nature, our current searches would not recognise it!*

In this analogue paradigm which is appropriate to biological brains, when electromagnetic radiation in a visible spectrum v_s impinges on a three-dimensional object o_i an interference pattern $P(o_i,v_s)$ can be produced which defines the nature of information in a new paradigm. Furthermore the process of perception is the recovery of the object image $o_i'(v_s)$ from such a pattern $P(o_i,v_s)$ such that o_i and $o_i'(v_s)$ coincide. And the process of cognition is simply the ability to store such interference patterns and the ability to compare them. To demonstrate that such processes take place in human brains, simply snap your fingers at some point about your head and observe the direction, intensity and location of the acoustic object image your brain creates. It is located outside your head at the precise point at which your fingers snapped so that the object image and the object do indeed coincide. Now focus your eyes on a close object and reach out and touch it. Your fingers tell you that the tactile object image your brain creates is located exactly, in every particular, where your eyes tell you the visual object image which the brain also creates is to be found [3].

Secondly if this model of brains is correct as the above simple experiments indicate may be the case, then such an analogue computer or brain would be the result on Earth of guided evolution using such interference effects in a quantum system that was initially a suitably constituted chemical soup in a radiation or heat bath [6]. In which case, the Huygens' model says, the possible end result of such an evolution would be a classical wavefield apparatus prepared with interference pattern data from the senses, and capable of quantum mechanical computations or measurements [7]. Such an apparatus, which was able to compute quantum mechanically in order to more accurately perceive and cognize, would do so by interaction with the non-classical medium of the dynamic quantum vacuum where interference effects concern probability waves. This means that human brains employ quantum non-locality in order to function and this may be understood better in computational language by saying that they employ the natural synchrony that exists at the quantum level between all physical processes in order to switch from one mode of functionality to another instantaneously. Such an ability to switch from one massively parallel computation to another, is an obvious advantage to survival, and has indeed been observed in human brains, where such experiments demonstrate that, as the model implies, such switching requires no central control [8]. *The existence of such natural instantaneous synchrony at the quantum level between all physical processes of which the brain is a naturally evolved user, points to a potential means - the human brain itself - by means of which the limitations of transmission of the speed of light can be partially overcome.* I say partially because such use of natural instantaneous synchrony is a probabilistic phenomenon as it concerns message or image transfer. In this case the impending new science of parapsychology will encompass extra-terrestrial communications once brains are better understood on Earth. R. Penrose [10] and P. Marcer [11] indicate that such natural synchrony at the quantum level concerns quantum gravity and so might manifest itself in gravitational effects as well as through consciousness or mind.

Thus I believe that no intelligent extra-terrestrial understanding the nature of information and its function as it applies to the internal structure of the Universe, life and brains, would even attempt transmission of signals by the essentially classical means being employed in such searches currently on Earth unless their development by coincidence almost exactly parallelled our own and the assumption that information is of a binary nature. Transmissions are not on outer space at all, but on inner space at the quantum level and concern consciousness and quantum gravity.

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Chairman, Cybernetic Machine Specialist Group
The British Computer Society

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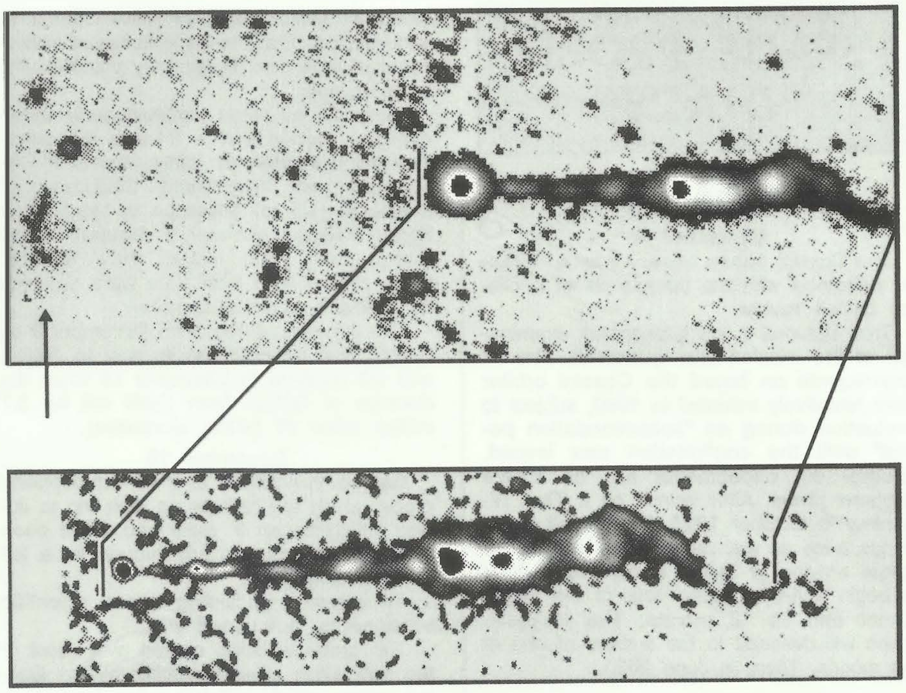
The Editor welcomes items of correspondence for publication. The right is reserved to shorten material as appropriate.

Astronomical Notebook

The Giant Galaxy M87

Messier 87 (M87), a giant galaxy, situated at the centre of one of the largest and nearest clusters of galaxies, the Virgo Cluster, is about 50 million light-years away. Several thousand galaxies belong to this cluster but none is brighter or more massive than M87 which is visible even in small telescopes.



Jets in the M87 Galaxy: Images of both of the jets in the giant galaxy Messier 87 obtained with the 2.5 metre Nordic Optical Telescope at La Palma, Canarian Islands, Spain, are recorded in "false-colours" to enhance the visibility of the delicate structures with different brightness.

The upper photo is a combined image from which the background light from the M87 has been subtracted. The main jet is on the right, while the newly-discovered arc-like structure representing the end of the counter-jet is visible at the extreme left (indicated by a vertical arrow).

The lower frame shows the image of the main jet computer sharpened. Individual knots are visible and represent the path of hte energetic particles emitted by the centre of M87, here seen as a point-like object to the left.

European Southern Observatory

An 'Invisible' Counter-Jet

Photographs taken in 1918 showed the presence of a jet in M87, a long, thin extension in a westerly direction from the centre of the galaxy. The jet bears witness to violent processes taking place at the centre of M87 and led to the suspicion that there is a giant black hole there. Recent observations with the Hubble Space Telescope have strengthened this suspicion.

M87 belongs to a select group of radio-emitting galaxies. The jet, particularly, emits intense radio-emission, caused by the interaction between a strong magnetic field and very energetic particles ejected from the centre. The same observations have also indicated the presence of a much more diffuse, rather symmetric radio-emission from much of the galaxy. However, contrary to most other radio galaxies, there has been no indication of the existence in M87 of a counter-jet in the opposite, eastward direction. This seemed to show that M87 must be a rather peculiar case and perhaps very different from other radio-galaxies with jets.

Now, optical images have been obtained which clearly show the presence of a counter-jet so, in this sense, M87 is less extraordinary than was previously thought.

The Giant Radio Galaxy M87

Photographed in visual light, M87 is one of the brightest of the elliptically shaped galaxies. It emits strongly at radio frequencies and is thus known as the radio-source Virgo A, one of the strongest in the sky.

M87 is about ten times brighter than our own Milky Way and contains more than one thousand billion stars like our Sun. The central density of its stars is at least 300 times greater than expected for a normal giant elliptical galaxy and over a thousand times more dense than the distribution of stars in the neighbourhood of the Sun. In fact, the ultimate central density of stars in M87 may be even higher but this measurement is beyond the resolving power even of HST.

Radio galaxies are divided into two classes, depending on their radio-brightness and also the degree of symmetry of the radio-emission. The radiation from galaxies of Type I is less powerful and less symmetric than that from galaxies of Type II. Until now, M87 had been classified as of Type I, mainly because of its asymmetrically placed but otherwise prominent single jet which stretches almost 6000 light-years to the west from the centre.

It is now believed that all the bright and symmetric radio-galaxies of Type II contain two diametrically opposite, powerful jets of energetic particles, mostly electrons which move with velocities very near to that of light and carry great quantities of energy from the centres to the outer regions of the galaxies. The radio emission observed from the jets is synchrotron radiation, i.e. the electromagnetic radiation emitted when the associated, strong magnetic field forces the energetic electrons to move in spiral-shaped orbits. Although most of the synchrotron radiation is emitted as radio waves, it has also been possible to observe this radiation at optical wavelengths in a few Type II radio galaxies.

The Counter-Jet in M87

Radio-observations of M87 show a diffuse emission on the other side of the main jet but do not provide clear evidence of the existence of a counter-jet. Earlier optical observations never showed anything either. However, the excellent images obtained under near-perfect observing conditions with the Nordic Optical Telescope (NOT), enabled ESO astronomers to detect an arc-shaped filament to the East of the centre of M87, i.e. in the opposite direction of the main jet. Assuming that the distance of M87 is 50 million light-years, the angular distance of the arc from the centre of M87 (~24 arcseconds) corresponds to about 6000 light-years. This is about a quarter of the distance of the Sun from the centre of the Milky Way Galaxy.

The new images of M87 were obtained in different wavelength bands so it was possible to measure the colour of the arc-shaped nebula accurately. It is reddish and corresponds closely to what would be expected from synchrotron emission. The conclusion is that the arc is shining by the same physical process responsible for the radio emission.

The Nature of the Counter-Jet

The counter-jet has the form of a hollow cone directed towards the far part of M87. It is surrounded by interstellar material through which the counter-jet has excavated its present path. As energetic electrons move a long distance inside the cone without emitting much energy, the corresponding part of the counter-jet is not visible. However, at the position of the arc-like structure, fast-moving electrons reach the end of the cone and are suddenly piled up and compress the interstellar medium so that strong synchrotron radiation is emitted. The counter-jet then becomes "visible" in optical light.

If the counter-jet could be "switched off", the arc-like filament would stop shining approximately 1500 years after the last electrons arrive, an extremely short period in astronomical terms. The fact that it is actually observed gives a strong indication that the counter-jet has been active for a long time and continues to be active.

SPACE PROBE DIARY

Cassini Saturn

December 9

The Cassini Saturn mission passed a major milestone with the completion of a critical design review.

This included a comprehensive examination of the mission and spacecraft. The 12 experiments on board the Cassini orbiter were tentatively selected in 1990, subject to evaluation during an "accommodation period" until the confirmation was issued. Another six experiments are on ESA's Huygens probe. After launch on a Titan IV-Centaur in October 1997, Cassini will fly by Venus twice as well as by Earth and Jupiter before arriving at Saturn in November 2004 to begin a 4-year orbital tour of the ringed planet and its 18 moons. The Huygens probe will descend to the surface of one of the moons, Titan, in June 2005.

Galileo

November 26

Galileo used one of its two small antennas to send to Earth the last of its 57 tape-recorded photographs of the 10.5 mile wide asteroid, Gaspra. Galileo took about 150 pictures while passing within 1,000 miles of Gaspra on November 29, 1992.

December 8

Galileo's flyby took place at 10:09 am EST at an altitude of 189 miles (304 kilometres) above the South Atlantic Ocean, completing a 3-year gravity-assist programme and setting a course to reach Jupiter on 7 December 1995.

This third gravity-assist for Galileo added about 8,280 miles (13,300 km) per hour to its speed in solar orbit and changed its direction slightly so that its elliptical orbit will now reach to the orbit of Jupiter, about 480 million miles (780 million km) from the Sun.

En route to Earth encounter, Galileo flew about 68,000 miles (110,000 km) north of the Moon at 10:58 pm EST on December 7 and providing first-time photographs of the Moon's north pole. Departing from Earth in a slightly southerly direction, it again crossed the Moon's orbit at about 9:15 pm EST on December 8.

Galileo was programmed to measure the near-Earth environment and observe the Earth and Moon during flyby. This was to provide scientific data from new perspectives in some cases and help calibrate instruments for the Jupiter orbital mission in 1995-1997.

The Galileo orbiter will fly ten different elliptical orbits of Jupiter with close passes by each of the major satellites and extended observations of the planet and its magnetosphere. Its atmospheric probe, will descend into Jupiter's atmosphere on December 7, 1995.

December 9

A Major milestone in space communications was passed with the successful transmission of laser signals to the Galileo spacecraft at a distance of 1.3 million miles (2.2 million km). The experiment, called the Galileo Optical Experiment (GOPEX) is part of a programme to show that future deep space missions can use laser beams to send back to Earth larger volumes of space-acquired data than is currently possible with radio signals.

Laser beams were simultaneously transmitted to Galileo from a 24-inch (61 cm-diameter) telescope at Table Mountain Observatory near Wrightwood, California and a 60-inch (1.5 m) telescope at the US Air Force Phillips Laboratory's Starfire Optical Range near Albuquerque, New Mexico. Laser beams from both sites were detected by Galileo's onboard camera.

The experiment began on December 9 as Galileo flew by Earth on its way to Jupiter and will continue to December 16 when the distance of Galileo from Earth will be 3.7 million miles (6 million kilometres).

December 15

Galileo spacecraft and its atmospheric probe, which are halfway on their trip to Jupiter which began 3 years ago, have been fully checked out and run through for a full mission sequence.

All systems, including seven scientific instruments, functioned well.

The probe is being carried over most of the half billion miles to Jupiter by the Galileo orbiter. At 51,358,400 miles from Jupiter, the probe will separate from the orbiter and fly on by itself. This will occur on July 10, 1995, 5 months before arrival at Jupiter.

On December 7, 1995, the probe will make the first entry into the atmosphere of an outer planet. It will be injected into Jupiter's atmosphere at 115,000 mph. Deceleration to about Mach 1 - the speed of sound - will take just a few minutes, causing a buildup of heat as intense as flying through a nuclear explosion.

The Galileo probe will then plunge 400 miles through Jupiter's brilliantly coloured cloud layers into the hot, dense atmosphere below. Entry into Jupiter's atmosphere will be most hazardous because the planet's gravitational pull creates tremendous speeds. The probe then decelerates from 115,000 mph to 100 mph. Its incandescent shock wave will probably be as bright as the Sun and reach temperatures up to 28,000 degrees F. After entry, the fore and aft heat shields of the deceleration module will be shed by deploying a small pilot parachute and then a large main chute, exposing the descent module to Jupiter's hydrogen/helium atmosphere.

The probe's total weight is 747 pounds. The deceleration module weighs 484 pounds. The inner descent module carries seven scientific instruments, weighing 66 pounds which, together, will characterise Jupiter's ionosphere and its atmosphere (composition, temperature and density), measure wind speeds, cloud characteristics, lightning, the important ratio of helium to hydrogen and the atmosphere's energy balance.

As the probe passes through Jupiter's coloured cloud layers, its computer will receive information, process it and transmit the coded signal to the Galileo orbiter, which will relay the data by radio to Earth. The probe descent mission will last about 75 minutes. At this point, a combination of extreme heat, high pressure and degraded battery power will silence the probe forever.

December 28

Last ditch attempts are being made to open Galileo's stuck main antenna, a problem that threatens to hamper the exploration of Jupiter. Further endeavours will be made over the next weeks.

Mariner 2

December 14

Thirty years ago, on December 14, 1962, Mariner 2, the first successful interplanetary probe reached Venus after a 108-day journey from Earth. It was a 450 pound (200 kg) machine carrying six scientific instruments, a two-way radio, a solar power system and assorted electronic and mechanical devices.

The Mariner planetary spacecraft series began in 1960 as a group of mission studies at JPL. By 1975 there had been 10 Mariner flights, seven of them successful explorations of the inner Solar System. Mariner 2 became the model for planetary space flights. The Mariner 2 mission was authorised by NASA in August 1961, less than a year before the first launch window. The limited capacity of Atlas/Agena, the largest launch vehicle then available, severely restricted launch opportunities and spacecraft size.

The first launch, Mariner 1, was aborted when its launch vehicle strayed from the safe flight corridor and was destroyed by the Range Safety Officer.

Mars Observer

December 7

The laser altimeter on NASA's Mars Observer spacecraft has undergone a successful three-hour test. The test occurred after the spacecraft had travelled more than 17 million miles on its journey to the red planet.

Mars Observer Laser Altimeter (MOLA) will send a laser beam to the Martian surface and measure the time of flight to yield a topographical map of the planet with vertical precision of approximately five feet. The laser beam footprint forms a square with sides of about 240 feet from an altitude of nearly 250 miles. The MOLA diode-pumped laser transmitter will be required to fire at a rate of 10 shots per second i.e. about 600 million shots will be required. By sorting the returning pulse into one of four width categories, the MOLA will be able to determine the average slope or equivalent roughness of the observed terrain.

Tests of similar devices in the laboratory have demonstrated lifetimes in excess of a billion shots.

December 11

The radio science flight sequence is winding down and scheduled for completion on December 14, 1992. The next flight sequence will prepare the spacecraft for its transition to the outer cruise flight mode in which the high-gain antenna will be used. The outer cruise attitude transition begins on December 15, 1992. The Mars Observer camera "bakeout" to prepare the instrument for operation will continue in this next sequence until December 28, 1992.

An experiment to observe the Earth's geotail at a greater distance than reached by other spacecraft began on December 9, 1992. The geotail is the region where the solar wind is disturbed as the Earth orbits the Sun. The experiment will use Mars Observer's magnetometer and electron reflectometer to gather data on solar and magnetic particle disruption caused.

Star-ephemeris tables, uploaded about once a week, continue to adjust the spacecraft's solar panels so that they are beginning to point more directly at the Sun: the high-gain antenna is pointing more directly at Earth. These adjustments are planned to

continue until January 2, 1993, when the high-gain antenna will be pointing directly at Earth.

The spacecraft is now about 16 million miles (25 million km) from Earth, travelling at a speed of about 15,000 miles (23,500 km) per hour relative to Earth. The spacecraft has a heliocentric velocity of about 66,000 miles (105,000 km) per hour.

Ulysses

December 11

Routine Earth-pointing manoeuvres continue to be conducted about every five days, the last on December 9 and the next on December 14. Ulysses' on-board tape recorders are to be switched on on December 12. Tape recorder 2 will become the primary recorder and tape recorder 1 will be a backup unit.

A reduction in the number of ranging passes continued to improve the spacecraft signal at its great distance from Earth. Ulysses is about 760 million miles (million km 470) from Earth, travelling at a heliocentric velocity of about 20,600 miles (32,500 km) per hour. The spacecraft is 14.3 degrees south of the ecliptic plane in which the planets orbit, slowly looping its way back toward the Sun. The Kepler Gas Experiment to measure neutral helium gas from interstellar space was turned on again on December 9. Measurement of the arrival speed and direction of the interstellar gas allows scientists to determine how the solar system is moving through interstellar space. With Ulysses now more than 14 degrees out of the ecliptic plane, speed and direction can be determined more accurately by including third dimension measurements.

Yohkoh

December 23

Following launch from the Kagoshima Space Center in Southern Japan on 30 August, 1991, Yohkoh has now completed its first full calendar year in orbit. All its instruments, designed to obtain high resolution Solar X-ray images and spectra, are producing excellent results. The spacecraft's large bubble memory is read out routinely both to the Japanese command and control ground station and to the NASA Deep Space Network so that an almost complete solar coverage is obtained.

To date, Yohkoh' X-ray telescope has produced more than a million images of the Sun's Corona and of Solar Flares at angular resolutions of up to 3 arc seconds. The corona or outer part of the Sun's atmosphere is shown to be far more dynamic than was previously suspected, with constant changes occurring in its large-scale magnetic structure and some evidence for outflows of hot plasma from active regions where the existence of a closed magnetic field structure was thought to prevent material from leaving the corona.

The novel hard X-ray telescope, which produces images with 5 arc seconds resolution at energies up to 100 keV, has been used along with the high spectral resolution Bragg crystal spectrometer to clarify the connection between the sudden release of huge amounts of energy in flares and the appearance of 50 million degree plasma in the corona.

It is anticipated that Yohkoh, with an envisaged orbital lifetime of up ten years, will provide the next major steps forward in the field of Solar Physics.

EUVE "Sees" Object Two Billion Light Years Away

A powerful exotic object, two billion light-years beyond the Milky Way galaxy, designated PKS 2155-304, was observed by the Extreme Ultraviolet Explorer (EUVE) Spacecraft, launched into Earth orbit on June 7 to search the spectrum between visible light and x-rays, a little explored region of the extreme uv portion of the electromagnetic spectrum.

Observations of the EUV spectrum both inside and out of the Milky Way galaxy is usually blocked by gas and dust in interstellar space. However, it is unevenly distributed and this allows the EUVE telescopes to see distant sources of radiation.

The object appears to be a tremendously energetic elliptical galaxy that radiates as much energy as a trillion suns. Such a galaxy, called a "BL Lac Object", may contain a super-sized black hole at its centre with a mass of 100 millions suns, which makes it a possible cousin to the more mysterious quasars.

BL Lac Objects vary dramatically in brightness in all other spectral regions but PKS 2155-304 was rock steady in the EUV for a day and a half.

"It might be that we have found the right window to see the steady infall of material onto the giant black hole that the theorists think may be at the very centre of this object", said Dr Kondo.

The EUVE satellite is undertaking a survey of the entire sky. It will provide the first detailed maps in several EUV energy bands. Radiation at these energies is emitted by multi-million degree coronae on stars, by giant eruptions on novae, by the hot surfaces of white dwarfs and by sources in the BL Lac objects.

Arecibo Improvements

Significant improvements are to be made to the world's largest and most powerful radio-radar telescope, the Arecibo Observatory, to enhance its ability to observe radio signals from distant objects.

A $23 million grant over the next few years will enable a complete change to be made in the telescope's optics (the way in which incoming radio waves are focused), a doubling to one megawatt of power of the transmitter used for radar studies of the solar system, and a 50-foot-high steel mesh "fence" around the perimeter of the 1,000 foot (305-metre) reflector to reduce the level of background radio noise which interferes with the reception of signals.

The upgrading will increase the sensitivity of the telescope by a factor of about 20 for studies of the solar system and a factor of about three for studies of distant galaxies. It will result in use of more radio frequencies and increased sensitivity at all frequencies.

A radio and radar telescope differs from an optical telescope in a key respect. With an optical telescope, light waves are collected by the human eye, photographic film or sensors, whereas a radio telescope collects electromagnetic waves, or radiation at radio wavelengths. Clouds, haze, even daylight, therefore, do not interfere with the signals. The reflector collects these signals and focuses them on feed antennae suspended from two carriage houses held by a 600-ton platform over the reflector. Receivers inside the carriage house send the signals by cable to the ground where they are digitised and put into a computer.

Planned improvements will replace the suspended line feeds with two reflectors and a horn feed. One radio carriage house will be replaced as well, with a reflector combination of two 80-foot and 30-foot mirrors encased in a dome. The whole structure will be as tall as a six-storey building, about 60-feet high, weighing 90 tons. Cables and towers will be reinforced. The work is expected to be completed in early 1994.

The reflector "dish" itself will not change. At 1,000-feet in diameter and 167 feet deep, the dish is made of 40,000 perforated aluminium panels, each about 3 by 6-feet, supported by a network of steel cables. Each panel is adjustable to maintain a precise sphere that varies less than 0.12 inches over the entire 20-acre surface.

The reflector has the world's largest, and most sensitive, curved focusing antenna. While other radio telescopes require hours to collect enough energy for analysis, Arecibo can perform the task in minutes. Its sensitivity has allowed astronomers to see quasars 10 billion light years away (near the edge of the observable universe), distant galaxies, pulsars, and interstellar clouds. It operates in the frequency range of 50 MHz to 5,000 MHz.

Unexpected Transient Radiation Source

The Compton Gamma Ray Observatory has discovered an unusually strong source of X-rays and gamma-rays in Perseus in an area where there is no identifiable source.

The radiation intensified shortly after discovery and appears to be the brightest source of its kind ever seen.

Outbursts like this are thought to originate in binary star systems which contain an ordinary star orbiting with a compact star i.e. either a neutron star or a black hole. Outbursts are believed to be triggered when a large amount of material is suddenly released from the ordinary star and is pulled by the intense gravity of the other star to its surface. Transient events of this sort occur only once or twice a year. The new outburst had an unusual flickering and intensity and appeared at a much shorter wavelength than similar sources.

Launch Report

Shuttle Launches for 1993

Busy Year for Three-Orbiter Fleet

Following the successful launch of eight missions in 1992, NASA plans to launch eight shuttles again in 1993. This contrasts to six shuttle launches in 1991 and 1990, four launches in 1989 and two in 1988.

The OV-104 Atlantis orbiter is undergoing planned modifications at Palmdale, California throughout much of the year and will not be scheduled for any 1993 launch. All of 1993's shuttle missions will feature OV-102 Columbia, OV-103 Discovery or OV-105 Endeavour. The last year NASA operated a three-orbiter fleet throughout the entire year was 1991 which was a six mission year.

* * *

NASA begins its 1993 launch programme in mid-January with the launch of STS-54 carrying the TDRS-F communications and data relay satellite into orbit. The TDRS will be deployed from Endeavour and boosted into a geosynchronous orbit with an IUS booster. Also aboard the STS-54 mission will be the Diffuse X-Ray Spectrometer (DXS) payload which will study X-rays from such diffuse sources as ancient supernovas.

* * *

In late February STS-55 with Columbia will be launched carrying a Spacelab pressurised module. The Spacelab will be the second German Spacelab to fly on the shuttle. The SL-D2 payload, as it is designated, will provide the shuttle crew with access to a number of experiments and test apparatus located in the payload bay.

* * *

The last week in March will feature the planned launch of STS-56 with Discovery carrying the Spacelab programme ATLAS-2, the second of a series of unpressurised Spacelab pallets with instrumentation for studying the Earth's atmosphere from space. The first ATLAS flew on STS-45 in March of 1991. STS-56 also carries the Spartan 201 deployable solar physics satellite. Spartan will be deployed by Discovery and retrieved later on the same mission.

* * *

STS-57 with Endeavour, now scheduled for late April-early May will retrieve the Eureca satellite which was deployed by STS-46 in early August of last year. STS-57 will also have the first flight of the Spacehab programme, a commercial venture which features an extension to the orbiter middeck area projecting into the payload bay and allowing an extended set of middeck payloads to be carried. The Superfluid Helium On-Orbit Transfer or SHOOT payload will also fly on this mission and provide technology development data on the behaviour of superfluid helium in the microgravity environment. A set of Get Away Special, or GAS canisters, will fly in the orbiter's payload bay as well.

* * *

July will have the launch of STS-51 with Discovery carrying the deployable Advanced Communications Satellite and its Transfer Orbit Stage (ACTS/TOS) upper stage. ACTS will provide experimental data in such communications areas as multibeam antennas, on-board baseband processing, Ka-band technologies, and other promising technologies for future communications satellites. STS-51 will deploy and later retrieve the ORFEUS/SPAS, a set of instruments which will study astronomical characteristics in far and extreme ultraviolet regions of the spectrum and which are mounted on the SPAS free-flyer satellite.

* * *

STS-58, in late August, will feature a reflight of 1991's successful STS-40 Spacelab Life Sciences payload, SLS-1. SLS-2, aboard Columbia will extend the Life Sciences studies using a Spacelab pressurised module to build on the studies of the SLS-1 and also investigate new areas of life studies in microgravity.

* * *

In mid-November STS-60 will feature the second flight of a Spacehab middeck extension module, this time aboard Discovery. STS-60 will also carry the Wake Shield Facility (WSF), a deployable free-flyer which uses a shield to deflect residual atmospheric components and produce a very low vacuum area for epitaxy studies prior to retrieval; and the Capillary Pump Loop payload (CAPL) which is a Hitchhiker programme payload studying heat pipe characteristics and which is mounted on a cross-bay structure in the payload bay.

* * *

The final mission of 1993 will be the STS-61 flight with Endeavour providing the first repair and maintenance visit to the Hubble Space Telescope. This mission will include servicing the Hubble payload as well as replacing several components of the astronomical payload. TS-61 is planned for early December.

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SATELLITE DIGEST-249

Satellite Digest is our regular listing of world space launches. Orbital data has been reproduced from the RAE Table of Earth Satellites, produced by the Aerospace Division of the Defense Research Agency.

Name and International Designation	Notes	Launch Date	Launch Vehicle	Perigee (km)	Apogee (km)	Period (min.)	Incln. (deg.)
RESURS-500, 1992-75A	(1)	15.91 Nov 1992	Soyuz	303	187	89.46	82.58
KOSMOS 2219, 1992-76A		21.9 Nov 1992	Zenit	849	855	102.00	71.01
KOSMOS 2220, 1992-77A		20.65 Nov 1992	Soyuz	167	342	89.62	67.14
MSTI, 1992-78A	(2)	21.57 Nov 1992	Scout	331	444	92.37	96.75
NAVSTAR 2A-07, 1992-79A		23.00 Nov 1992	Delta 2	19926	20279	714.72	54.83
KOSMOS 2221, 1992-80A		24.18 Nov 1992	Tsiklon	636	665	97.80	82.51
KOSMOS 2222, 1992-81A		25.51 Nov 1992	Molniya	591	39288	708.15	62.88
GORIZONT 27, 1992-82A		27.55 Nov 1992	Proton	36469	36523	1472.38	1.46
USA 86, 1992-83A		28.90 Nov 1992	Titan 4	Orbital data not released			

NOTES

(1) Europe-American-500 Programme. Recovered in the Pacific Ocean by the Marshal-Krylov 320 km SW of Seattle, USA.
(2) Miniature Seeker Technology Integration for SDIO.

STS-53: Weather Delays Liftoff

Cloud Diverts Landing

The Space Shuttle Discovery lifted off from the Kennedy Space Center's Launch Complex 39A on December 2, 1992 at 8:24 am on mission STS-53. The launch had been scheduled for 6:59 am that morning; however, cold weather delayed the launch until 8:24 am. Temperature overnight had dipped to 47 degrees and a coat of ice and frost had accumulated around the cryogenic propellant areas of the Shuttle's External Tank.

During the ascent, a pressure sensor in the centre main liquid fuelled engine, engine no. 1, failed and gave erroneous readings. Other sensors on the engines, however, confirmed that the engine was operating properly and no cause for alarm existed. The Solid Rocket Boosters cutoff on schedule at 2 minutes 4 seconds into the mission and the main engines cutoff at 8 minutes and 42 seconds into the flight. Following the burn of its orbital manoeuvring engines Discovery was placed in a circular orbit at an inclination of 57 degrees and height of 200 nautical miles with all systems operating normally.

Commander of the five man STS-53 crew was David M. Walker who served in the same capacity on Mission STS-30 in May of 1989. Walker was also the pilot on STS-51A, his first space flight, in November of 1984. The STS-53 pilot was Robert D. Cabana who was also the pilot on the STS-41 mission in October of 1990. Mission specialist 1 was Guion S. Bluford Jr who was a veteran of STS-8, STS-61A and STS-39; during which he accumulated over 500 hours of space flight. James S. Voss was mission specialist 2 and had flown on STS-44 in November of 1991. Michael R. Clifford, mission specialist 3, was making his first flight on STS-53.

In addition to its classified Department of Defense primary payload, Discovery carried two unclassified secondary payloads in its payload bay.

After final preparations for the planned Kennedy Space Center Landing were completed the mission was diverted from KSC due to cloud cover. The STS-53 mission ended with touching down on the Edwards Air Force Base, California after 7 days, 7 hours, 19 minutes and 19 seconds of space flight. Discovery's main gear touched down on runway 22 at 3:43:17 pm Florida time on December 9, 1992 (local California time was 12:43:17 pm). Nose gear touchdown was at 3:44:04 and wheel stop at 3:45 pm.

*The STS-53 Mission Report will appear in the March 1993 issue of **Spaceflight**.*

First Step With Russian Partners

STS-60 Crew Arrangements

Charles F. Bolden, Jr. will command Space Shuttle mission STS-60 in November 1993. Other crew members are Pilot Kenneth S. Reightler, Jr. and mission specialists Franklin R. Chang-Diaz, N. Jan Davis, Ronald M. Sega, and an experienced Russian cosmonaut.

Bolden, 46, piloted two Space Shuttle missions, STS-61C in January 1986 and STS-31 in April 1990 and commanded the Atmospheric Laboratory for Applications and Science mission STS-45 in March 1992. He was appointed Assistant Deputy Administrator at NASA Headquarters in Washington, DC, in April 1992.

Reightler, 41, was Pilot on Space Shuttle mission STS-48 on which the crew successfully deployed the Upper Atmosphere Research Satellite. His current assignment is Chief of the Mission Support Branch in the Astronaut Office and Lead CAPCOM in Mission Control, responsible for communications with Space Shuttle crew members during flight.

Chang-Diaz, 42, is a veteran of three space flights - STS-61C in January 1986, STS-34 in October 1989 and STS-46 in August 1992. He was selected to become an astronaut in 1980.

Davis, 38, flew on STS-47 Spacelab-J, a cooperative mission with the National Space Development Agency of Japan, in September 1992. Selected to become an astronaut in June 1987, Davis has a doctorate in mechanical engineering from the University of Alabama, Huntsville.

Sega, 39, was selected in January 1990 and this will be his first space flight. Sega is an Adjunct Professor of Physics at the University of Houston and is a Co-Principal Investigator of the Wake Shield Facility which is manifested for this flight.

An experienced cosmonaut will fly aboard the STS-60 Space Shuttle mission. The Russian Space Agency has nominated Col. Vladimir G. Titov and Sergei K. Krikalev to undergo mission specialist training. One cosmonaut will be designated the prime crew member and the other designated backup crew member.

Mission objectives include a number of microgravity experiments in Spacehab-2, the Wake Shield Facility experiment to test the creation of an ultra-vacuum in which to produce extremely pure thin film crystals for industrial uses ranging from microelectronics to lasers and superconductivity, a Capillary Pumped Loop Experiment to study a method of heat dissipation in space and a number of Getaway Specials flown in a bridge assembly in the orbiter's payload bay. Additionally, Russian Space Agency-sponsored life science activities will be included in the mission.

STS-54: Liftoff for Endeavour

On 13 January 1993 at 8:53 am EST, the Space Shuttle Endeavour was successfully launched at the Kennedy Space Center on the first shuttle mission of 1993. A seven-minute delay arose due to last-minute weather checks and adjustments to the orbiter's flight equipment and computer programs. Two minutes after liftoff, Endeavour's twin solid boosters peeled away and dropped into the Atlantic Ocean. The shuttle then reached orbit at a height of 184 miles on the thrust of its three liquid-fuelled engines.

The primary purpose of the mission was the launch of a fifth Tracking and Data Relay Satellite into geostationary orbit. This 2½ ton satellite, costing $200 million, is one of a series of satellites that pass information between ground control stations and orbiting spacecraft, including the shuttle itself and the Hubble Space Telescope. One such satellite was destroyed in the 1986 Challenger accident.

On reaching orbit, Endeavour's cargo bay doors were opened and six hours later the satellite was successfully released. A booster rocket attached to the satellite then propelled it toward a 22,300-mile-high orbit.

Endeavour is equipped with an improved toilet which is making its space debut. The item has been criticised by Congress' General Accounting Office because of its cost of $23 million.

Future Flights for SAREX

The year ahead looks a very interesting one for SAREX, the Shuttle Amateur Radio Experiment.

The next flight is STS-55 which is currently scheduled to fly in February 1993. The inclination is 28.5 degrees. The US amateurs are Steve Nagel, N5RAW, CDR, and Jerry Ross, N5SCW, PL-CDR. The SAREX configuration will be Config C, which is 2 M FM voice and packet. There will be another amateur radio experiment aboard the D2 Space Lab called SAFEX which will be operated by German amateur operators. SAFEX is FM voice on 70 cm. SAFEX will utilise an external dual band (2 M/70 cm) antenna mounted on the Space lab while SAREX will use the existing window antenna that mounts in either window 1 or 6.

The second flight in 1993 will be STS-56 which is scheduled for a night launch in March. The inclination is 57 degrees. The amateurs are Ken Cameron, N5AWP, CDR, Den Cockrell, KB5UAH, MS, Mike Foale, KB5UAC, MS, and Ellen Ochoa, KB5TZZ, MS. The SAREX configuration is Config D which supports voice, packet, SSTV and FSTV.

The third SAREX flight in 1993 will be aboard STS-57 which is scheduled for launch in late April-early May. The inclination is 28.5 degrees. Brian Duffy, N5WQW, PLT, is the amateur operator. The SAREX configuration will be Config C.

International Space Report

Vehicle-Mounted Satellite Terminal

FERRANTI INTERNATIONAL, Stockport, UK is to supply key elements of a mobile Ku-Band satellite communications system being developed for the Australian Department of Defence. The work will be undertaken in Poynton, Cheshire under a £2 million contract from British Aerospace Australia Limited, the prime contractor for the 'Parakeet' project. The complete terminal system with a 2.4 metre antenna will be mounted on a six-wheel Land Rover vehicle.

Somalia Coverage

INTELSAT, Washington DC. The antenna platform on the Intelsat 502 satellite has been rotated in order to provide the four leading US television news networks (ABC, CBS, CNN and NBC) with direct links from Somalia to their distribution centres in the United States. The networks have television channels available 24 hours a day. As a result of the 502's rotation which can be maintained indefinitely, all of that satellite's coverage areas (or footprints) have been shifted as far east as possible without affecting existing service. The Intelsat 502 is located just off the west coast of Africa.

Earth Observation Study

LOGICA, London has been selected by the European Space Agency (ESA) to lead an international consortium of 18 companies from eight countries in Europe and Canada to study the design of the polar orbiting mission ground segment. The mission comprises a series of scientific instruments which will fly onboard the Polar Platform satellite, plus the associated ground segment which will provide the instrument data products and supporting information necessary to further our understanding of a number of Earth-related phenomena such as global warming, deforestation and ozone depletion. The study is valued at more than £3 million and will last 15 months. The first polar orbiting mission will be launched in 1998.

Soyuz for Station Emergency

NASA, Washington, DC - The feasibility of using the Soyuz TM spacecraft as an Assured Crew Return Vehicle (ACRV) for astronauts aboard the Space Station Freedom has been discussed between NASA and NPO Energiya in working group meetings at the Johnson Space Center (JSC), Houston.

Space Age 'Clean Room' for UK Firm

AVICA EQUIPMENT, Hemel Hempstead is the only UK company participating in the current Ariane 5 project after being awarded a multi-million pound contract to manufacture high strength nickel-alloy ducting to be used on the rocket's main Vulcain engine.

It is supplying a total of seven 'ducts' for the first stage Vulcain engine, the cryogenic fuel source for which will be a mix of liquid oxygen and hydrogen. Two are 'hot' ducts withstanding temperature of up to 700°C as they carry oxygen and hydrogen gas along the 60 mm diameter pipes at 300 kg/second. Three are 'cold' ducts of 90 mm diameter carrying liquid oxygen and hydrogen at temperatures down to -240°C, while the final ducts, each with a diameter of 220 mm, will operate as exhausts for two turbo-pumps, subject to temperatures as high as 750°C.

As part of its on-going commitment to the Ariane space programme, Avica Equipment has opened an environmentally controlled 'clean room', which has taken a year to plan and install and will enable Avica to provide quality-assured components and ducts using a multiple wash/rinse and particle analysis process. A three-stage washing process uses an ultrasonic alkaline solution, a deionised water rinse followed by a ultrasonic de-ionised water rinse. Components are then put through a two-stage drying process. Fibre optic inspections follow each cycle which is designed to measure particle contamination down to 5 microns. The 'clean room' meets Ariane conformance criteria to Class 100,000 Federal Standard 209, Issue D.

Croatia Joins Inmarsat

INMARSAT, London - Croatia has become the 66th country to join Inmarsat, the Inmarsat operating agreement being signed by the Croatian Ambassador in London.

Located on the Adriatic Sea, Croatia has 12 established shipping companies with a total of nearly 400 vessels and its own classification society for vessels - the Croatian Register of Shipping.

Inmarsat's services are expected to support Croatia's maritime, land transport and airline industries.

The country already has 70 Inmarsat terminals in operation on ships though most of these vessels carry foreign flags due to political changes in the past few years.

During recent periods of political instability, mobile satellite communications via Inmarsat, have proved invaluable to towns such as Vukovar and Dubrovnik, providing the only means for communicating with relief organisations for obtaining humanitarian and medical aid.

Private companies, journalists, relief organisations and members of the United Nations protection organisations have found Inmarsat's mobile satellite communications critical for maintaining contact with the rest of the world, particularly from areas where terrestrial links have been damaged or are non-existent.

Space Materials and Structures Institute

SANDIA NATIONAL LABORATORIES, Alberquerque, New Mexico - Three major laboratories, namely the US Air Force's Phillips Laboratory, Sandia National Laboratories and Los Alamos National Laboratory, have established an Institute for Advanced Space Materials and Structures to increase the reliability of US spacecraft and space-based systems.

The experience with the Hubble Space Telescope, a satellite for basic scientific research, has illustrated the high cost of repairing spacecraft on-orbit. Evidence suggests that a large number of space-based failures are due to the interaction of a variety of space environmental factors that degrade spacecraft materials or create incompatibilities between structures and materials.

The new institute will qualify new materials, processes, and structural concepts for use in space systems. It will draw upon existing DOD and DOE programmes related to space technology and combine the strengths of Phillips, Sandia and Los Alamos in an integrated programme.

Transfer of space technology to industry will be an Institute policy.

Thermal Imager Tests Solar Cells

Thermograms Help CNES Identify Potential Faults

AGEMA INFRARED SYSTEMS, Leighton Buzzard, UK, a Spectra-Physics Company is supplier of the Thermovision 880LWB thermal imager to the French National Space Research Centre (CNES) where advanced infrared thermography techniques help to analyse the thermal behaviour of components in space.

As the solar generator of a medium-sized satellite generating between 2 and 3 kW requires about 40,000 such cells, it is essential to have an accurate assessment of their behaviour in space.

The solar generator comes under enormous stress in space. Thermal shocks causing temperature variations in excess of 200°C can induce huge thermoelastic stresses, while cosmic and solar radiation as well as the Earth's radiation belts can also inflict serious damage.

The French Space Agency has set up an artificial space environment which will allow an accurate determination of the electrical and thermal characteristics of solar cells in space.

Damaged cells become polarised and cease to be generators. Acting like receivers, the cells become thermally excited and create localised hot spots.

Similarly, cells which have become delaminated will also heat up faster and reach extremely high temperatures. There is also a risk that the cells, the cover-glass or the connectors might become damaged during a thermal cycle.

Traditional temperature measurement techniques, using thermocouples, are not effective in any of these cases. Their physical contact prevents the solar radiation from reaching parts of the solar generator, so distorting the electrical measurements and introducing errors which cannot be compensated for, even using calibration.

Since hot spots are very local phenomena, thermocouples would also need to be very densely packed to achieve the same level of thermal mapping as that provided by an infrared thermal imaging system.

Infrared thermography is the only non-destructive technique that can provide sufficient thermal data. Comparing thermograms captured before and after endurance tests makes it possible to identify a range of faults characterised by their own temperature difference. As a real time system, the AGEMA THV880LWB is able to monitor the rapid temperature changes which occur within the hot spot.

Solar Sail Experiment

WORLD SPACE FOUNDATION, South Pasadena, California:

...The (Znamya solar sail) experiment is planned (for) early February 1993. The experiment (is) connected with the date of (the) Progress spacecraft to be undocked from the Mir orbital complex...the next Soyuz spacecraft is to be docked January 26, 1993 to the side port of the Mir.

Vladimir Syromiatnikov, Consortium Space Regatta *(Supplied by Robert L. Staehle).*

Proton Contract

INMARSAT, London has decided to award a contract to DB Salyut of the Russian Federation for the launch of an Inmarsat-3 satellite on a Proton rocket from the Baikonur Cosmodrome. Inmarsat will incur additional costs related to this launch in ensuring compatibility of the vehicle and launch support services and there is also the possibility of incurring additional expenses because of the pioneering nature of the launch.

In March 1992, Inmarsat awarded a launch contract to General Dynamics of the United States for the first two of its Inmarsat-3 satellites in 1994. The third will be on Ariane, scheduled for launch in mid-1995, and the fourth on Proton, to be launched at the end of 1995.

Turbojet-Boosted Pegasus

ORBITAL SCIENCES CORPORATION, Fairfax, Virginia has announced the design of Pegasus Turbo TM, which is an air-breathing turbojet booster stage and is expected to achieve substantial payload performance increases and cost-to-orbit decreases compared to all-rocket-propelled launch vehicles. It is scheduled for first launch in 1993. Like Pegasus and Pegasus XL, Pegasus Turbo would be air-launched from a carrier aircraft and would use a wing to aerodynamically assist its ascent trajectory. It would be capable of placing a 2250-lb satellite into a 28 degree inclination, 160 nautical miles circular orbit, a 125% increase over Pegasus XL's 1000-lb payload capacity. Since the new vehicle's cost is expected to increase by only about 25-30% compared to the basic rocket, Pegasus Turbo should achieve a 40% decrease in cost-per-pound of payload to orbit. Further, the new rocket is designed to have a gross weight at aircraft separation of 68,000 lb, only 35% heavier than its predecessor. As a result, its payload-to-gross weight fraction should increase to approximately 3.3% from 2.0%, making it a highly mass-efficient launch vehicle.

Japanese Contract

In 1994 an Ariane rocket is to launch a new direct broadcast satellite for Japan following the signing of the launch contract of the BS-3N satellite. The satellite will be operated jointly by NHK (Japan Broadcasting Corporation) and JSB (Japan Satellite Broadcasting Inc.) and will have a liftoff mass of 1200 kg.

VHSIC Electronics for Space Systems

THE HONEYWELL SPACE SYSTEMS GROUP, Clearwater, Florida, which has been at the forefront of using Very High Speed Integrated Circuit (VHSIC) electronics in spaceborne computers for more than 10 years and is a pioneer in the development of radiation-hardened VHSIC electronics is also developing next generation products in submicron VHSIC and Silicon-on-oxide Insulator (SIMOX) technologies.

To date Honeywell has successfully applied its Generic VHSIC Spaceborne Computer (GVSC) and other VHSIC electronics in many space system applications such as the:

- ❑ Advanced Spaceborne Computer Module (ASCM): a very fault-tolerant space computer for control applications and sensor processing requiring multi-processors;
- ❑ Advanced Satellite Technology III (AST III): an experimental satellite that will be launched by the Air Force Phillips Laboratory;
- ❑ Midcourse Space Experiment (MSX): two GVSC-based computers that will be utilised for attitude control and sensor processing;
- ❑ MILSTAR (Military Communications Satellite): Honeywell has provided critical VHSIC electronics to TRW in the development of the MILSTAR Advanced Computer. MILSTAR requirements for reliability and strategic-level radiation hardness have resulted in very rigorous characterisation testing of all VHSIC parts.

Honeywell sees a bright future for space systems. Its VHSIC foundry in Plymouth, Minn. has been one of the first to receive DESC qualification as a Qualified Manufacturers List (QML) supplier of VHSIC parts. The company has recently demonstrated a new way of developing complex space computers on the ASCM programme in conjunction with development of a control processor module (CPM). The CPM is a highly fault-tolerant, GVSC-based, radiation-hardened computer which comprises 20 unique VHSIC part types. Eleven of these devices were new developments for the CPM. Honeywell has also developed an extensive system, subassembly and chip-level simulation of the entire computer in the VHSIC higher-order description language (VHDL) which replaces the traditional functional breadboard. "We are now able to take our prototype unit directly into qualification testing and will wipe out an apparent schedule difference at a significantly lower total programme cost. The future for space systems is VHDL and QML", according to Bob Campbell, ASCM programme manager.

Honeywell Space Systems Group, with operations in Clearwater, Florida, Phoenix, Houston, Huntsville, Alabama and Durham, North Carolina, is a leader in the design, development and production of control subsystems and equipment for manned and unmanned space applications. Honeywell is a global controls company that provides products, systems and services for homes and buildings, industry and aviation and space. The company employs 58,000 people worldwide and had 1991 sales of $6.2 billion.

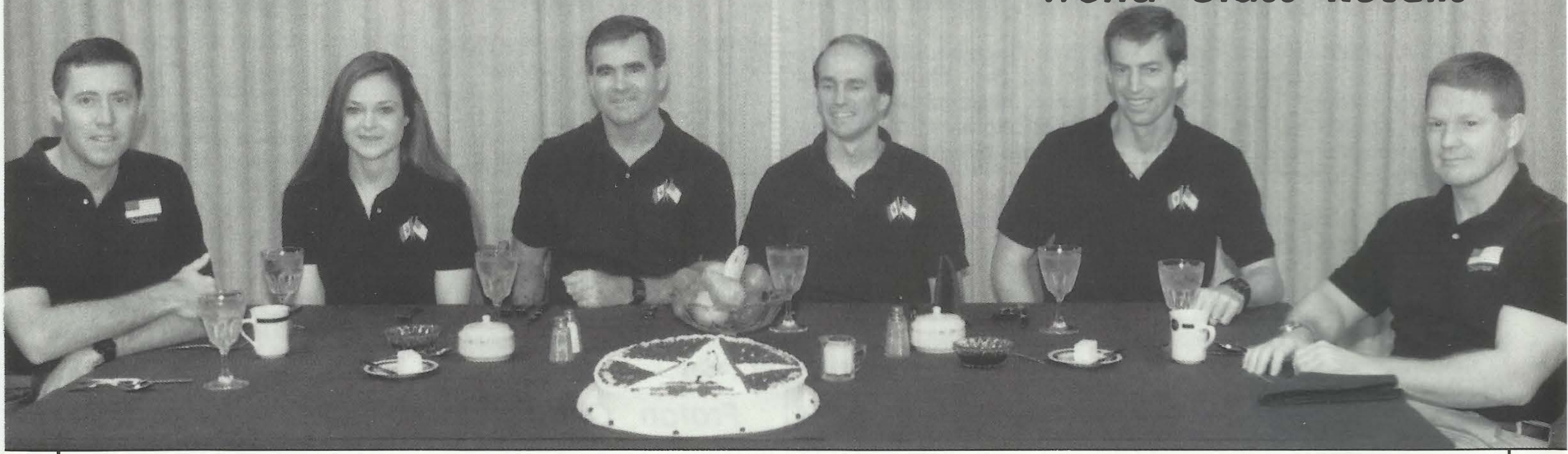
Romantis to Expand Links with CIS

DEUTSCHE AEROSPACE, Munich - The German company Telekom, the Russian company Business Sviaz and the Dornier-led Satellites and Application Systems Division of Deutsche Aerospace AG have signed a trilateral agreement covering the initial project Romantis. The project's aim is to tap the market for satellite telephone services between the CIS and Western Europe.

Telekom will provide access to the international telephone network, the required satellite capacity via Intelsat VI and will organise the charge accounting. DASA will supply the Earth stations and is responsible for the engineering. Business Sviaz handles logistic activities in Moscow and the marketing.

Columbia Mission

STS-52
MSFC Scientists Report 'World Class Results'



In the Operations and Checkout Building, the STS-52 flight crew enjoys breakfast before suiting up and departing for Launch Pad 39B. From left are Pilot Michael A. Baker; Mission Specialists Tamara E. Jernigan and Charles Lacy Veach; Payload Specialist Steven G. MacLean; Commander James D. Wetherbee and Mission Specialist William M. Shepherd. *NASA*

Telescience is Put to the Test

Despite winds that occasionally gusted above the 15 knot limit for an emergency return landing at the Kennedy Space Center, the Shuttle Columbia was launched at 1:09:39 pm from Launch Complex 39B on October 22, 1992. The launch had been scheduled for 11:16 am but weather concerns at the launch site and the transatlantic emergency landing abort sites caused a delay of almost two hours. The Johnson Space Center Flight Director for the launch, Jeff Bantle, was concerned about the weather but decided to go ahead with the launch. At KSC, Deputy Shuttle Program Manager, Brewster Shaw, indicated that the management team felt they had a safe situation and were operating within the intent of the rule. Winds were about 12 knots at the time of launch.

BY ROELOF SCHUILING
At the Kennedy Space Center

The primary objectives of the mission included the deployment of the Laser Geodynamic Satellite (LAGEOS), a 24 inch sphere studded with 426 reflectors which will allow ground researchers to make accurate geological distance measurements by reflecting laser beams from the LAGEOS, and operation of the United States Microgravity Payload-1 (USMP-1) which contained three experiments to study material sciences in microgravity.

Preparations

Assembly and integration of the USMP-1 payload began at KSC on January 28, 1992. The Italian-built LAGEOS arrived at the Florida launch site for assembly and checkout on March 24, 1992. The primary payloads were assembled, integrated and tested throughout the spring and summer and were transported to the Launch Pad on September 18, to await the arrival of Columbia.

Secondary payloads included the CANEX-2, a complement of seven microgravity experiments located in the payload bay and middeck which were operated by Canadian payload specialist MacLean and the Attitude Sensor Package (ASP) a Goddard Space Flight Center Hitchhiker Program payload mounted on the payload bay wall to evaluate three attitude sensors for use in space programme operation. The Tank Pressure Control Experiment/Thermal Phenomena (TPCE/TP), also mounted in the payload bay, studied technology for controlling cryogenic fuel tank pressures in low gravity environments.

Middeck secondary payloads included studies of materials dispersion, crystal growth, vapour transport, heat pipe operation and rodent physiological studies.

The orbiter processing for the STS-52 mission began with Columbia's landing at KSC following the STS-50 mission on July 9. The orbiter was moved into the Orbiter Processing Facility's work bay No. 1 on July 10 and spent the next 73 days being prepared for the STS-52 mission. The STS-50 mission payload - the United States microgravity Laboratory Spacelab and its personnel transfer tunnel - were removed from Columbia's payload bay together with the support systems for the Spacelab payload. The STS-50 flight engines were also removed and, on August 21, STS-52 engine installation began.

On September 26 the complete assembled Shuttle was moved to the launch pad. Connections between the Shuttle and the launch complex were tested and the payload complement of the USMP-1 and LAGEOS was installed in the payload bay.

Integrated testing of the USMP-1 and the orbiter was carried out on October 3 to verify payload-to-orbiter connections. LAGEOS integrated tests were performed on October 11. Main engine three removal and replacement operations began on September 28 and were completed by October 8.

Countdown and Launch

The countdown for STS-52 commenced at 4:00 pm on Monday, October 19, at the T-43 hour mark. The STS-52 flight crew arrived at KSC on the evening of Monday the 19th, in preparation for Thursday's launch.

Crew Members

The Columbia mission was under the Command of James D. Wetherbee who had previously flown on mission STS-32R as pilot. STS-52 pilot was Michael A. Baker, who also served as pilot on STS-43. Mission specialists for the flight were William M. Shepherd, who had flown as mission specialist on STS-27 and STS-41; Tamara E. Jernigan, PhD, a veteran of STS-40 and Charles Lacy Veach, who had joined the astronaut corps and had flown as mission specialist on STS-39. Payload specialist for the mission was Canadian astronaut Steven G. MacLean, PhD who was making his first flight in space. Three of the STS-52 flight crew, *viz* Baker, Jernigan and Veach, were making their second flights within eighteen months.

The countdown entered its first built-in hold at T-27 hours, which lasted from 8:00 am to 12:00 noon on the 20th. When the count resumed, the pad was cleared of all nonessential personnel for the loading of the fuel cell reactants. During the afternoon the reactants were loaded into the storage system. Following the loading procedure the midbody umbilical which is used to load the reactants was demated from the orbiter during a built-in hold which extended from 8:00 pm to 12:00 midnight.

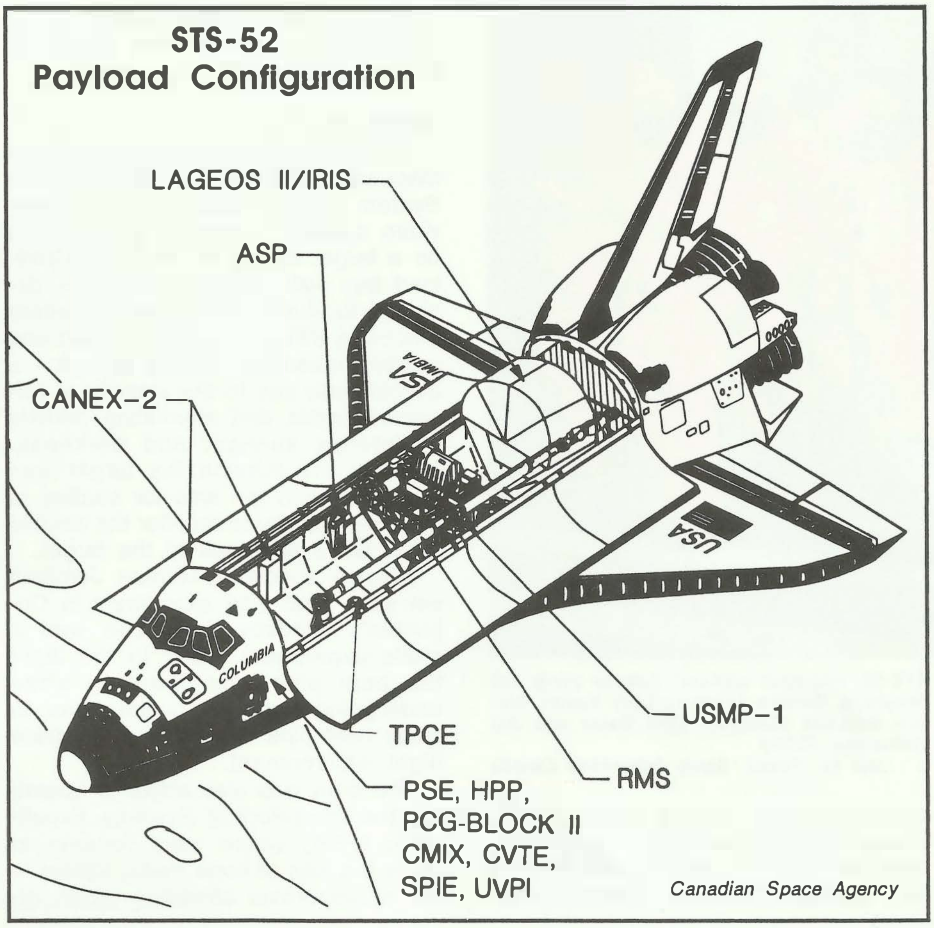
The stowable mission specialist seats were then installed In the flight and middeck areas. For ascent, the flight deck mission specialist seats were occupied by William M. Shepherd and Charles L. Veach with Tamara Jernigan and Steven MacLean in the middeck seats. For descent, Jernigan moved to the flight and Veach to the middeck seats.

The crew arrived at the launch pad at about 8:30 am on October 22 for entering the orbiter. The countdown proceeded as planned with a 10 minute built-in hold at the T-20 point and an additional 10 minutes hold at the T-9 minute hold. Due to concern about wind gusts at possible emergency abort landing sites, the countdown did not resume at the planned end of the T-9 minutes hold: this was continued as weather analysis and management teams assessed the situation. Mission managers decided that the STS-52 mission could be safely launched and, at approximately 1:00 pm, the countdown was resumed.

Following countdown resumption, the cabin access arm was retracted at T-7:30 minutes and the orbiter's Auxiliary Power System was started at the T-5 minute point. Liquid oxygen and hydrogen tanks in the External Tank were pressurized. At T-31 seconds the electronic "Go" was given to the orbiters computers to start their own terminal countdown sequence.

The main engine ignition sequence began at T-6.6 seconds with engines 3, 2 and 1 firing at 120 millisecond intervals. The main engines reached rated power in about 4 seconds. Approximately 2 seconds later, at T-0, the Solid Rocket Boosters ignited to send Columbia on its mission.

The main engines started at 100% power and were throttled back to 67% power at about 25 seconds into the flight to reduce aerodynamic loads as the Shuttle passed through the region of maximum aerodynamic pressure. The main engines were throttled back up to 104% power at about 62 seconds into the flight. The Solid Rocket Boosters stopped firing at launch plus 124 seconds and were jettisoned. The flight continued on the main engines at 104% power until 452.5 seconds when the engines throttled back at 3 Gs until reaching 70% power. At about 505 seconds the engines were reduced to 67% and main engine cutoff came at approximately 511 seconds into the flight.



After completion of the main engine portion of the flight, Columbia separated from the External Tank and performed a manoeuvring system engine burn to make a direct insertion into its 28.45 degree inclination orbit.

Flight Day One

Following arrival on orbit, the payload bay door opening operation was completed about one hour and thirty minutes into the flight.

About two and a half hours into the mission, the United States Microgravity Payload (USMP) was powered up and within another hour all three of the USMP's experiments had been activated. The MEPHISTO directional solidification furnace and the Lambda Point Experiment (LPE) were making their first space flight on USMP. The USMP-mounted Space Acceleration Measurement System (SAMS) experiment had been flown on five previous shuttle missions but this was the first time it had flown in the orbiter's payload bay.

All three USMP experiments were operated by scientists at the Marshall Space Flight Center (MSFC) after the USMP power-up by the flight crew, in what could be considered a "dress rehearsal" for telescience operations aboard the Space Station.

At launch plus six hours the crew began presleep operations. The crew's first sleep period lasted from approximately nine to seventeen hours into the mission. As the mission progressed the crew's sleep periods were gradually adjusted to earlier periods to bring their activity schedule into synchronisation with the planned landing time. The MET (Mission Elapsed Time) days were, therefore, slightly offset from the flight crew's days.

Following checkout of the satellite, the LAGEOS-II was successfully deployed from the Columbia at 9:56 am on Friday, October 23, by mission specialist Tamara Jernigan. The satellite was first spun-up in the payload bay to provide stabilisation. At 45 minutes after its deployment, the LAGEOS-II solid rockets' firing sequence began. Both rockets fired successfully and the geodynamics satellite was on its way to its 3,666 mile orbit where its 426 laser reflectors will permit accurate mapping of the Earth's surface to be made. This is the second LAGEOS to be orbited. However, its angle of inclination is 52 degrees whereas the first LAGEOS, launched from an expendable launch vehicle in 1976, had a 110 degrees inclination. The successful firing of the IRIS Italian-made upper stage also qualifies that unit for future Shuttle-deployed satellites. LAGEOS-II is now in an orbit that is sufficiently stable to last for 8 million years.

Mission commander Wetherbee

STS-52 astronaut walkout: (left to right) Bill Shepherd, Tamara Jernigan, Lacy Veach, Steven MacLean (Canada), Mike Baker and Jim Wetherbee (CDR).
Joel W. Powell, Space Information Canada

performed two Orbital Manoeuvring System firings to lower Columbia's orbit from 163 by 160 nautical miles to 155 nautical miles. The lower orbit was to accommodate experiments on the USMP and to allow a larger number of landing opportunities on return.

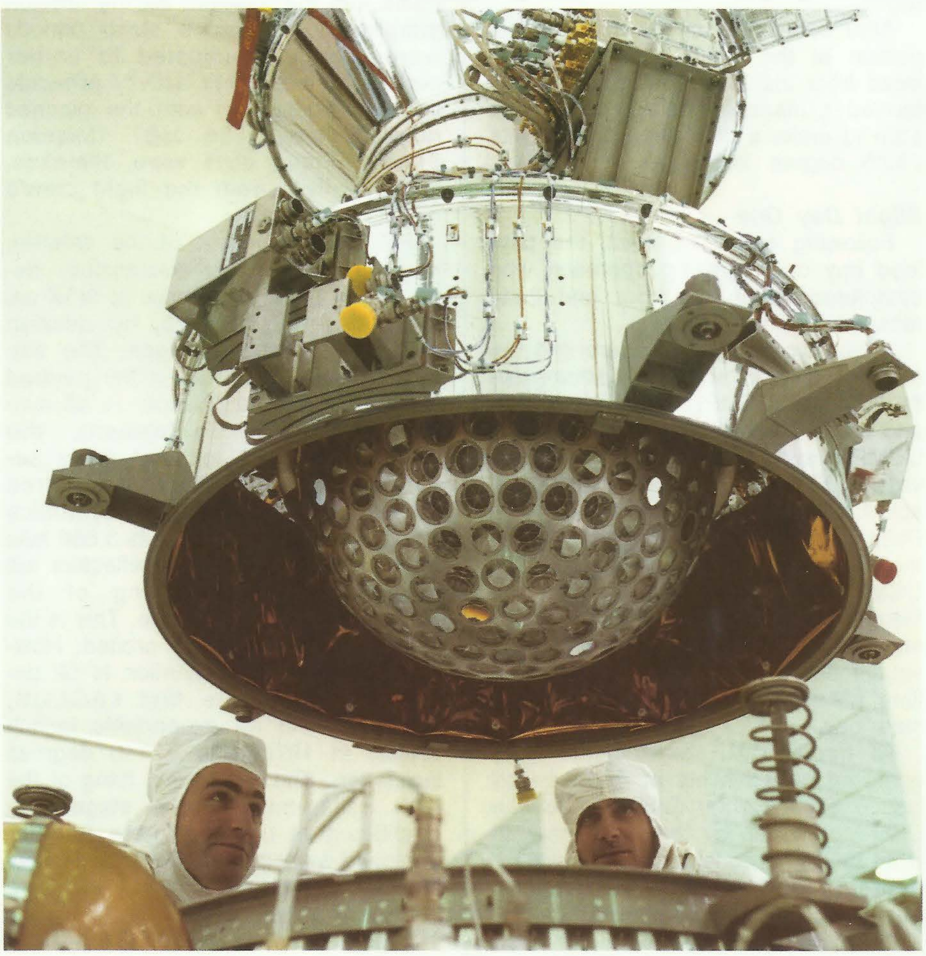
Flight Day Two

Canadian payload specialist, Steve MacLean, activated the Space Vision System (SVS) which uses a Shuttle video camera to monitor dot patterns on a target affixed to the Shuttle payload bay wall. The experiment is designed to study vision in space where it is often difficult to gauge motion and relative speeds of moving objects - a difficult task due to the scarcity of reference points and alternating periods of intense sunlight and darkness. Later in the mission the target was detached from the wall for studies of the crew's ability to monitor the Shuttle robot arm's approach to the target.

Mission specialist Tamara Jernigan set up a heat pipe experiment in Columbia's middeck area. This was a static experiment. Later in the flight the heat pipe was operated while undergoing various accelerations to study heat pipe operations in a space flight environment.

The crew was also active in operating the Physiological Systems Experiment (PSE) which uses rodents to study the loss of bone mass, similar to the osteoporosis condition which affects many people on Earth. The PSE on STS-52 investigated a protein molecule's ability to reduce such bone mass loss.

In the Spacecraft Assembly and Encapsulation Facility 2 (SAEF 2), a key processing milestone is achieved as workers carefully mate the hoisted Laser Geodynamic Satellite (LAGEOS) with the Italian Research Interim Stage (IRIS). The spherical LAGEOS spacecraft, covered with retroreflectors, is already attached to a LAGEOS apogee stage (uppermost portion of LAGEOS assembly). *NASA*



Flight Day Three

LAGEOS program scientists reported that the satellite had been successfully tracked by four laser stations located in Australia, Easter Island, California and Maryland. Ground stations were able to meet requirements for predicting the satellite's appearance within 200 milliseconds.

Meanwhile, aboard Columbia, Bill Shepherd and Jim Wetherbee were test subjects for the Lower Body Negative Pressure Device (LBNP). The LBNP has flown on a number of Shuttle missions and lowers the pressure around the lower part of the body, thereby imitating gravity's effects by pulling fluids downward. This experiment helps scientists to study the effects of microgravity on the Shuttle's crews and evaluates the LBNP as a countermeasure for the dizziness sometimes experienced by crews when they return to Earth and readapt to gravity.

Mission specialist Veach and payload specialist Maclean completed two segments of testing with the SVS machine vision system. Manoeuvring Columbia's robot arm, Veach grappled, moved and replaced the small target assembly several times with the assistance of MacLean. The SVS, a Canadian experiment, is hoped to provide information which will aid in construction of the Space Station on-orbit.

Mission specialist Jernigan again operated the Heat Pipe Performance experiment. Operations included spinning the experiment at various rates to simulate different levels of spacecraft acceleration forces.

The crew worked with the Sun Photospectrometer Earth Atmosphere Measurement (SPEAM) and Phase Partitioning in Liquids (PALIQ) experiments. However, the QUELD liquid metal diffusion experiment was experiencing a balky fan and was set aside as ground experts investigated the problem. The Attitude Sensor Package (ASP) payload ground investigators reported experiencing erratic data from one of two channels recording yaw data. The other yaw data channel continued to function successfully.

The study of crystal formation in space continued as mission specialist Bill Shepherd worked with the Crystals by Vapour Transport Experiment (CVTE) and commander Jim Wetherbee and pilot Mike Baker worked with the Commercial Protein Crystal Growth (CPCG) experiments on the Shuttle's middeck.

Canadian payload specialist Steve

MacLean worked with two optical experiments. One, SPEAM, looked at various wavelengths of light reflected from the Earth's upper atmosphere and another, OGLOW, photographed the orbiter glow phenomenon as the Shuttle surfaces encountered residual atomic oxygen in low Earth orbit.

Tests of the tin-bismuth alloy sample in the USMP's MEPHISTO directional solidification furnace revealed uniform quality along a six-inch sample. The MEPHISTO sensors allow experimenters on the ground to visualise solidification as it occurs. The furnace was running at slightly better than expected rates, allowing experimenters to repeat two experiment stages at a time when there was more motion aboard Columbia so that sample comparisons could be made later on the ground.

The USMP LPE (Lambda Point Experiment) team completed calibration of their instrument, designed to study the dynamics of matter near the transition phase points - such as between liquid and gas phases - with accuracies 100 times better than those on the ground. The LPE team had begun collecting high-resolution data on their superfluid helium sample using ultrasensitive thermometers which were accurate to within billionths of a degree. Experiment manager Reuben Ruiz likened that accuracy with comparing the thickness of a human hair to the distance from Los Angeles to New York.

Flight Day Four

The CVTE (Crystals by Vapour Transport Experiment) apparatus continued to operate and ground personnel were able to assess experiment data *via* the modem on the crew's portable computer.

The crew again used the LBNP device with pilot Mike Baker performing the test, assisted by mission specialist Bill Shepherd.

Mission specialist Tamara Jernigan continued her work with the Heat Pipe Performance experiment and completed almost five hours with the unit.

An additional problem surfaced with furnace number 2 of the CVTE when it went into idle mode prematurely. The furnace was allowed to cool down prior to deactivation by the crew later in their work cycle.

Flight Day Five

As the crew prepared to begin their sleep cycle at five hours into the MET day, ground personnel were busy developing procedures for the in-flight maintenance of CMIX (Commercial Metals Dispersion Experiment). However, the investigators determined that a pin was locked in an incorrect position and could not be reached by the crew so that the in-flight maintenance could not be performed.

The LPE had initially operated in the automatic mode but experimenters were now operating in an interactive phase as the experiment reached the transition region for liquid helium. The transition area, 2.17 degrees Kelvin or minus 456 degrees Fahrenheit, was extensively studied as over six hundred commands were sent to the unit. Researchers indicated that the data would lead to a unique new test of phase transition theory in a region completely inaccessible in ground laboratories.

The flexibility of telescience allowed researchers to replan the original MEPHISTO experiment to study a host of interesting phenomena and to test theories that have far-reaching implications for crystal growth. Although experiment data was downlinked to the Huntsville facility at MSFC, it was also relayed to colleagues at the French Space Agency in Toulouse and the French Atomic Energy Commission at Grenoble - an operational test for future missions when decision-making responsibilities are to be shared.

Canadian payload specialist Steve MacLean performed studies of electric currents in naturally separating fluids to identify separated fluid behaviours. It is hoped that the data will provide information useful in developing techniques for purifying cells for transplanting or disease treatment on Earth.

Flight Day Six

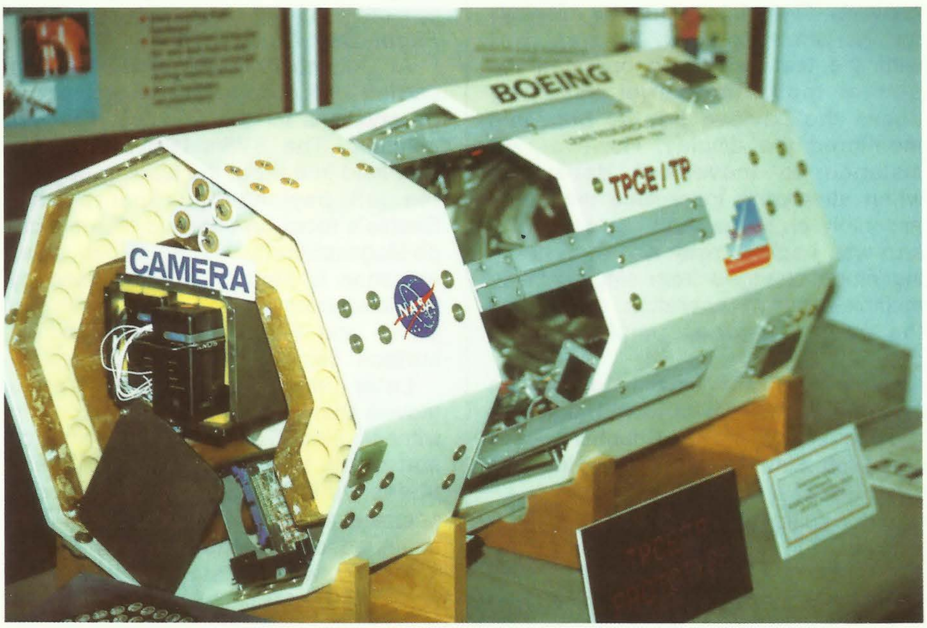
The Canadian experiment, called Materials Exposure to low Earth Orbit (MELEO), was operated for the first time on the flight. MELEO uses the Shuttle's robot arm to expose several materials mounted on the arm to the space environment in different positions.

The Space Shuttle Columbia thunders off Launch Pad 39B, embarking on a ten-day flight and carrying a crew of six. Lift-off occurred at 1:09:39 pm EDT on October 22, 1992. *NASA*

The Shuttle Columbia continued to perform well although the Test and Graphic system, a type of onboard FAX machine, jammed. However, printed material could still be sent to the orbiter *via* a teleprinter air-to-ground computer modem.

Operations with the USMP were going well and investigators working with the MEPHISTO directional solidification furnace and LPE decided to extend the experiments working time further into the mission. The permission timelines had called for deactivation of the MEPHISTO toward the close of the sixth MET flight day, and for LPE deactivation about 22 hours later. The additional experimental time allowed investigators to take data

TPCE/TP experiment (prototype apparatus) from STS-52 mission photographed at KSC. The cylinder fits inside a standard GAS can. *Joel W. Powell, Space Information Canada*



on the effects of certain microgravity disturbances, such as those caused by Shuttle manoeuvres. Assistant USMP mission scientists Dr Don Giles said "Their data will help define how extensively Shuttle manoeuvres affect crystal growth. That information will be extremely valuable in planning future experiments".

The LPE continued to acquire high-resolution data on the transition of helium from its superfluid condition to normal fluid state. Since its activation earlier in the mission, the LPE had passed through the transition temperature more than 40 times. Plans now called for continual runs until the experiment depleted its supply of helium. The LPE, in addition to providing data on the transition point, also carried charged particle detectors which would now be left powered-up until just before landing, in order to collect data as the Shuttle orbited through the South Atlantic Magnetic Anomaly area.

Shortly before the end of the sixth MET day the entire crew participated in a long-distance phone call between Columbia and the Polynesian sailing canoe "Hokulea". The Hokulea is a replica of ancient Polynesian sailing canoes used to train young navigators in the ancestral navigation techniques used by early Polynesian voyagers travelling the vast distances of the Pacific Ocean. After speaking with the crew of the Hokulea, who were then on a voyage toward Hawaii, the Columbia crew joined the Hokulea crew in speaking with school children in Hawaii and answering their questions. Mission specialist Charles Lacy Veach's hometown is Honolulu, Hawaii.

Flight Day Seven

Crewmembers Veach and MacLean completed the fourth in a series of evaluations of the SVS computer vision system. The computerised eye takes video views from a camera and converts them into computer displays for the arm's operator. All went well with the test as Veach operated the arm to move the target assembly above the payload bay as MacLean monitored the display. However, resistance to movement developed when attempting to replace the target assembly on its payload bay rack. The arm was backed away and the operating mode changed from single-joint to multiple-armjoint operating mode and the operation was completed successfully.

The crew was active in operations with the LBNP as pilot Mike Baker and mission specialist Bill Shepherd each spent 50-minute sessions in the device.

The additional operating time of the MEPHISTO and LPE instruments allowed investigators to continue the telescience type activity which had already involved over 1,800 commands from the MSFC ground controllers to the payload in the orbiter payload bay.

Flight Day Eight

The Columbia's crew held an orbital press conference in which they answered questions from journalists at the Johnson and Kennedy Space Centers. Later, Canadian payload specialist MacLean spoke with Canada's Science Minister, The Honorable William Winegard, by long-distance phone hookup.

USMP experiments continued to take data and Mission Scientist Dr Sandor Lehoczky noted, "The mission has been an unqualified success. Results obtained from these experiments are expected to make major contributions to the fields of condensed matter physics and materials science".

Columbia's crew completed three more tests of the computerised SVS vision system as Canadian payload specialist Steve MacLean and mission specialists Jernigan and Veach operated the system and the Shuttle's robot arm. Tests of the ability to judge the amount of flex in Columbia's robot arm when tracking a moving object and guiding the end of the arm through precise manoeuvres were carried out. Following this activity, the target assembly for the vision system was returned to its payload bay wall mounting location without difficulty. The robot arm was then turned off and latched down in preparation for the Shuttle's manoeuvring system engine firings.

Two manoeuvring system engine firings of approximately half a minute each were made to lower Columbia's orbit to 113 by 114 nautical miles. The low orbit optimised landing opportunities and also permitted additional data to be acquired on residual atomic oxygen effects on orbiting spacecraft.

Flight Day Nine

At Columbia's lower orbit MacLean carried out a series of photographic observations for the OGLOW glow experiment. The SVS's target assembly was held in front of the leading edge of the left payload bay door by the Shuttle's robot arm to study the effects photographically. The Glow phenomenon is thought to be caused by the interaction of high velocity oxygen atoms and the effect of the orbiter's surface temperature.

Later, mission specialist Veach moved the arm into position exposing witness plates affixed to the arm as part of the MELEO experiment. These plates held a variety of material samples and the arm was left in the extended position as the crew slept.

The crew was later awakened on schedule by Mission Control playing a record of the song "Monster Mash" in honour of the day being Haloween.

MALEO experiment activity was concluded and the CMIX dispersion experiment was deactivated.

After the crew members had completed their Space Vision System activities with the target held by the Shuttle's robot arm, the SVS target assembly was released from Columbia and tracked by the SVS experiment. As commander Jim Wetherbee flew formation with the target 140 feet away, MacLean reported the SVS accurately measured the distance although jet firings from Columbia made the video images degrade. The target assembly later reentered the atmosphere and burned up.

Preparations for the landing were begun as instruments were checked and crew compartment stowage activities were in progress. The crew performed tests of Columbia's flight systems in preparation for the planned landing.

Flight Day Ten

Shortly after awakening at about 12:24 am on the morning of November 1, the crew reported that separator fan number one of the orbiter's waste containment system had failed. The crew switched to the backup fan for the short remainder of the mission.

Final preparations for the landing were made and Columbia fired its manoeuvring system engines for about 39 minutes before touchdown, to slow the spacecraft for reentry.

Landing came on orbit 159 on the Kennedy Space Center runway 33 at 9:05:53 KSC-time. That equated to a Mission Elapsed Time of 9 days, 20 hours, 56 minutes and 13 seconds. The drag chute was deployed from Columbia's tail about 15 seconds later. Nose gear touchdown came 4 seconds after that. Following the release of the drag chutes, wheel stop was at Mission Elapsed Time 9 days, 20 hours, 57 minutes and 14 seconds. NASA's official record keeping designates the end of the mission time as the main gear touchdown time.

Columbia had travelled 4,129,028 statute miles during the STS-52 flight, which was the 51st mission of the Shuttle program.

SOCIETY MEETINGS DIARY

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.
It may occasionally happen that, for reasons outside its control, the Society has to change the dates or topics of meetings. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always recheck the scheduled meetings in the latest issue.

3 February 1993 — 7 pm - 8.30 pm

Nuclear Power for Deep Space Missions?

F.J. Gardner & Dr A. Stevens
Rolls Royce and Associates Ltd

Nuclear power, in the form of radioisotopes, already enables missions into deep space where solar power is weak. The fission reactor gives much more power to mission planners and platform designers. It will enhance the electric propulsion option for deep space platforms and allow power-intensive payloads to be deployed.

This talk will review the history and issues of space nuclear power, discuss emerging options and review longer term concepts.

3 March 1993 — 7 pm - 8.30 pm

Armchair Interstellar Exploration

A.T. Lawton

Although he dreams and plans, it is very unlikely that many men will undertake manned interstellar flight. For those who will never go to the stars - the stars must come to him.

Developments in technology e.g. interferometry, large apertures, new types of high resolution detectors and high fidelity data links will enable this to happen.

As of now they allow us to see solar cycles on other Sun-like stars, detect planetary dust clouds around them and deduce the possible presence of Jupiter like planets.

These techniques can be extended with precision spectrometry to form a catalogue of stars with planetary systems closely resembling our own Solar System.

This is Armchair Interstellar Exploration whereby if we do go, or send a one way robot as proxy, we will have maximum chance of success in locating other life forms.

17 March 1993 — 7 pm - 8.30 pm

Mission Control and Control Centre Operations

D.E.B. Wilkins

The lecture will discuss spacecraft opertions in general, the technology involved and the practice of operations since the early days of space flight.

The lecture will not dwell on the historical aspects of spacecraft control though references will be made to the significant advances achieved in those early years, 1957 - 1969.

The lecture will be presented in three parts: Past, Present and Future, and will be based on the experience and activities of the speaker in the fields of Spacecraft Control and Systems Engineering.

The early NASA Manned Mission control methods will be briefly discussed and the ESA experience in scientific and applications missions described in some detail to expand discussion on Mission Control.

7 April 1993 — 7 pm - 8.30 pm

Cassini

Dr C. Cochrane

Cassini is a project planned by ESA and NASA for a spacecraft to survey the planet Saturn and its environs. During the journey to Saturn, fly-bys and investigations will by made of asteroids and Jupiter. After arrival at Saturn the spacecraft will orbit the planet for a further four years, using remote sensing to examine its satellites, rings and the planet itself. A sophisticated probe will be released in the first orbit to land on the mysterious moon Titan, to explore its atmosphere and surface.

The presentation will describe the scientific objectives of the mission, its trajectories and explain the engineering problems of the Titan Atmosphere Probe, concluding with a review the feasibility of the proposed solutions and present the innovative features of this fascinating mission.

5 May 1993 — 7 pm - 8.30 pm

Results from ERS-1

Dr G.E. Keyte
DRA Farnborough

The European Space Agency's ERS-1 satellite was one of the most complex remote sensing satellites ever launched. Despite its complexity, it has functioned almost perfectly since launch in 1991 and has enabled a wide range of research and application projects to be undertaken.

This paper briefly describes the main characteristics of the ERS-1 instruments and gives an account of their 'history' since launch. Some of the main results obtained from each of its instruments are reviewed, covering both the two microwave instruments (the Active Microwave Instrument and the Altimeter) as well as the instrument provided by the UK, the infra-red radiometer (ATSR). It will conclude by reviewing the future development of microwave remote sensing satellites after ERS-1.

SYMPOSIA & CONFERENCES

24 March 1993 — 10 am - 4.30 pm

European Rocketry in the 1930's

As part of the Society's Anniversary Year the History Working Group are holding a Symposium on European Rocketry in the 30's. Contributions have been invited from Germany, France, Russia and the UK. The 30's is seen as a particularly interesting decade in that much theoretical and practical work was undertaken that laid solid foundations for later projects.

Whilst much publicity has surrounded the experimental and theoretical work carried out in Germany an enormous amount was also carried out elsewhere, particularly in Russia. Much of this story has yet to be told.

Advance Registration is necessary.
Registration: Forms are available from the Executive Secretary. Please enclose a sae.

12 June 1993 — 10 am - 4.30 pm

Soviet Astronautics

This programme will include the following topics: New Developments in Soviet Cosmonautics, Cosmonaut Teams, Soviet Programmes in Historic perspective.
Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Offers of Papers: Authors wishing to present papers should contact the Executive Secretary.
Advance Registration is necessary.
Registration: Forms are available from the Executive Secretary. Please enclose a sae.

15 - 17 October 1993

SPACE '93: Space Initiatives

This Special Society two-day meeting to commemorate the Society's Diamond Jubilee, 1933 - 1993 will include updated versions of many of the papers originally scheduled for Space '92 but which were carried forward when Space '92 had to be deferred owing to the reduced support arising from the current widespread recession.
The main Technical Sessions will consider past, present and future initiatives in space exploration.

Offers of papers are invited. Please contact the Executive Secretary.
Advance Registration is necessary.
Details of the Programme and Registration Forms will be available from the Society in due course.

VISITS

31st March 1993

London Teleport
(Isle of Dogs)

A one-day visit with briefings and tour open to a limited number of members interested in the EUTELSAT and similar programmes.

Pre-registration is necessary. Details of programme and Registration forms are available from HQ on request.

21 May 1993

Royal Aircraft Establishment/Defence Research Agency
(Farnborough, Hants)

A one-day visit with briefing and tour open to a limited number of members interested in remote sensing, advanced propulsion systems etc.

Pre-registration is necessary. Details of Programme and Registration forms are available from HQ on request.

LIBRARY

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. Membership cards must be produced.

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Spaceflight

The International Magazine of Space and Astronautics

Into Orbit WITH Reusable Spacecraft

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- STS-53 MISSION WITH CLASSIFIED PAYLOAD
- HUNTSVILLE OPERATIONS CONTROL CENTER
- WORLDWIDE SPACE NEWS & LAUNCH REPORTS

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Spaceflight

The International Magazine of Space and Astronautics

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Vol. 35 No. 3 **MARCH 1993**

Front Cover: Latest configuraton of National Aerospaceplane. *NASA*

Spaceplanes - Back to

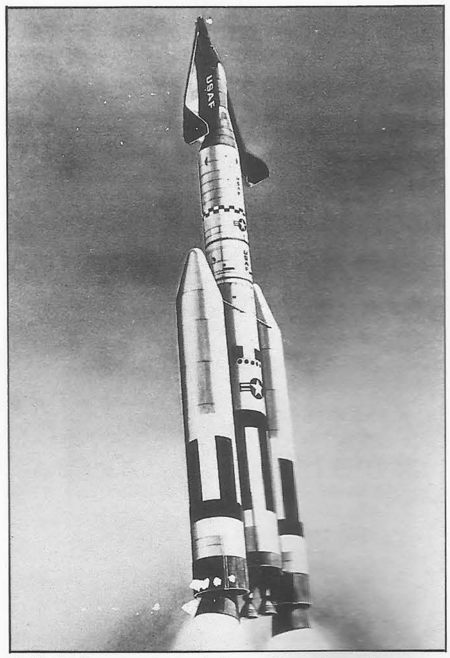
The Question of Money Seems Likely To Delay

An aeroplane is a powered, heavier than air vehicle which takes off from a runway and uses aerodynamic lift to keep it airborne. Its destination is another or the same runway. For the purposes of this article a spaceplane is a vehicle which takes off and lands like an ordinary aircraft but is also able to enter space.

Many are familiar with recent spaceplane programmes such as the UK's HOTOL, Germany's SÄNGER and the USA's NASP (National Aero-spaceplane). Each is a different concept to launch a winged reusable orbiter into space. All are still in the early stages of research and it is unlikely that we shall see any prototypes until the next century.

These spaceplane projects have been spurred by the need to reduce the cost of reaching a low Earth orbit. Their backers argue that, despite high capital expenditure on research and development, such reusable systems would eventually cut the cost of putting a payload into orbit by a significant factor. One can, however, go back to the pioneering days of space technology research to see that this aerodynamic approach is nothing new.

BY DOUG MILLARD
Science Museum, London



Artist's impression of Dyna-Soar launch. *Boeing*

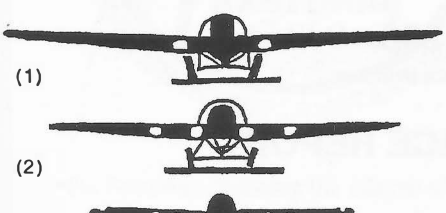
Oberth's Legacy

One of the greatest influences on the early rocket engineers was Hermann Oberth. His 1923 book "The Rocket into Interplanetary Space" explained with mathematics and text how space flight could be attained *via* the development of ballistic based rockets. History has born out his expendable launcher philosophy but this may be due to political expedient (Peenemunde, Sputnik, Kennedy and so on) rather than scientific logic.

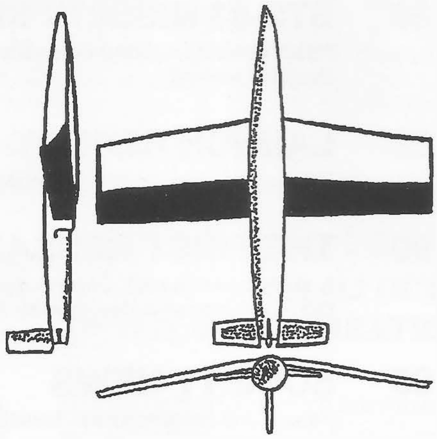
There were other engineers who acknowledged Oberth's vision but disagreed with his ballistic based methods. Max Valier, an Austrian science writer, put forward the idea of progressively converting a Junkers G-23 aircraft into a spaceship. A compatriot, Franz von Hoefft, outlined plans for a seaplane with an orbital third stage. However, it was Eugen Sänger, another Austrian, who analysed the aerodynamic route to space most systematically and went on to become one of the century's greatest proponents of space flight. His philosophy ran: stratosphere plane - spacecraft - spacestation - interplanetary spaceship - interstellar spaceship.

Max Valier's idea for cconverting a Junkers G-23 into a stratospheric plane and thence to a spaceship.

(1) 2 rocket motors added.
(2) 4 rocket motors added wing shortened.
(3) 6 rocket motors added wing shortened pressurised cabin.
(4) vertically launched spaceship.



Based on a lecture given at the British Interplanetary Society on October 7, 1992.



Sânger's Silverbird of 1933.

Sänger's Silverbirds

In 1933, whilst working at the Technische Hochschule in Vienna, Sanger published his design for a high altitude rocket plane. It was to have petrol and liquid oxygen propellants and reach velocities of about 10,000 km per hour and altitudes of between 60-70 km.

Towards the end of the 1930s Sänger issued another design which, in order to save weight, would be launched from a rocket driven sled accelerating to 1,800 km per hour. It is interesting to note that HOTOL is designed for launch from a trolley for the same reason.

Sänger referred to his craft as "Silverbird", though colleagues nicknamed it "Flatiron" in deference to its domed body and flat bottom.

With the onset of World War II, Sänger was required to adapt his craft for use by the German military. Thus, the "Racketenbomber" was born, a 100 tonne high altitude rocket plane which would be launched from a sled driven by two A4 rocket engines. Its liquid-propellant engine would develop 100 tonnes of thrust and achieve a maximum velocity of just under 29,000 km per hour. The vehicle would peak at an altitude of 300 km, after which it would descend and skip aerodynamically off the top layers of the atmosphere rather like a stone skimming across the surface of a lake. This skip flight trajectory would enable the craft to orbit the Earth and release its four tonne bomb over New York.

However, this project was cancelled in 1942 and Sänger saw the war out working on ramjet engines for fighter aircraft. It would be many years before he could return to his "Silverbirds".

Peenemünde's Wings

Sänger worked for the air force. At Peenemünde, on the Baltic coast, the German Army's ballistics programme was proceeding apace under the aegis of General Dornberger and the young von Braun. As well as honing the A4 missile. Dornberger's engineers also investigated winged rockets as a means of extending missile strike range.

The A4b was built and launched twice. On the first occasion it exploded almost immediately but on the second it became the first winged vehicle to

the Future

Spacelane Development

exceed the speed of sound. The Germans had even more ambitious plans with a piloted "A" variant which, like Sänger's Racketenbomber, would have been capable of bombing North America.

Post-War

If the thinking done in Europe during the 1930s represents a preliminary stage in spaceplane research, then the next phase probably occurred in the United States at the end of World War II.

Plans had been laid by the US Air Force in 1944 to tackle the sound barrier. This was broken in 1947 when Captain Yeager flew the X-1 research aircraft to Mach 1.06. The triumph was an overture for a succession of X-plane variants which nudged the speed and altitude records upwards.

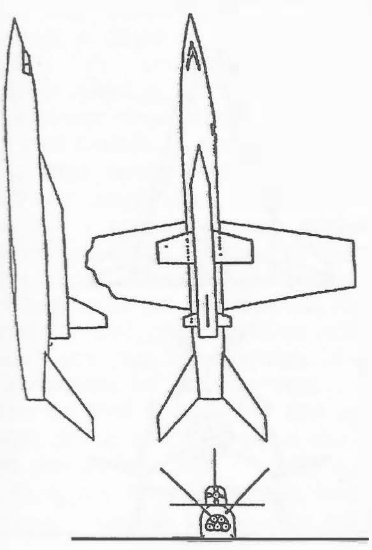
The next target was clearly to fly to the edge of space.

Calls were put out by the NACA (National Advisory Committee for Aeronautics) for vehicle designs. One of the proposals that came back in 1953 was the Drake-Carmen composite vehicle from NACA's own High Speed Flight Station. The upper stage of this TSTO (Two-Stage-To-Orbit) concept would separate at altitude and then boost to orbit before descending on a gliding flight path.

Many other designs were poured over but the craft which eventually received a go-ahead in 1955 was the X-15. This first flew in 1959 and went on to become the most successful high speed and altitude research aircraft ever built.

The X-15 flew to the edge of space. Indeed, the plane exceeded the threshold of 80.5 km (50 miles) on ten occasions and earned the pilots their astronaut wings. Everything augured well for the final target, that of developing a true orbital spaceplane.

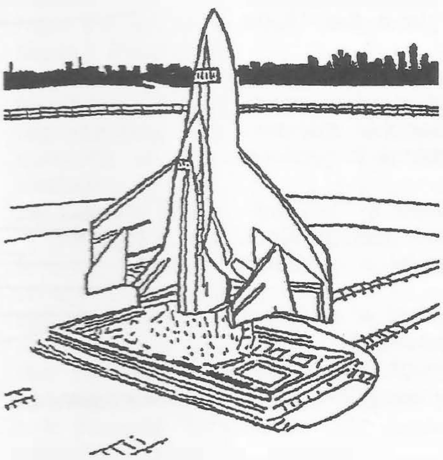
The NACA's Drake-Carmen TSTO Spaceplane.



Into Orbit?

During the early and mid-1950s the USAF had examined a range of orbital strike and reconnaissance craft concepts. BOMI (Bomber-Missile), devised by Walter Dornberger (late of Peenemunde), System 118P and Brass Bell were all conceived at the Bell Aircraft Corporation. ROBO was a winged orbital rocket bomber project under investigation in USAF research facilities. HYWARDS was to be a research aircraft aimed at validating the preceding systems.

Finally, in 1957 and, interestingly, just one week after Sputnik 1 had been launched by the Soviet Union, the USAF drew the various programmes together and announced the initiation of DYNA-SOAR (Dynamic-Soaring). This evolved into a small piloted delta-winged orbiter launched on a modified

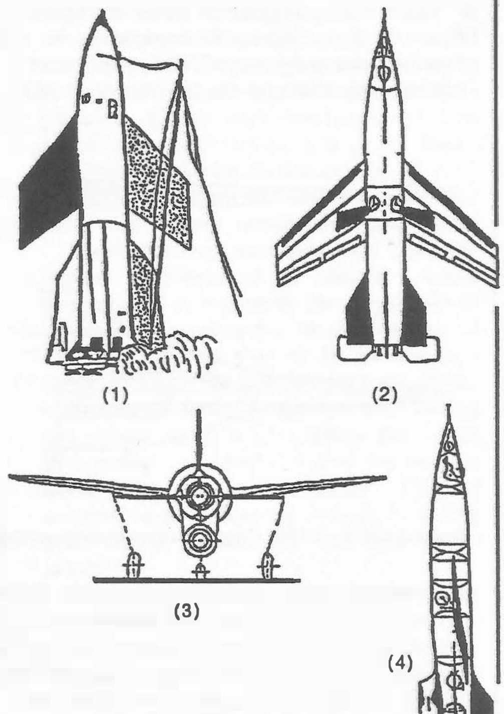


Dornberger and Bell's Bomi.

Titan booster. With an expendable booster system, however, it was clearly not a true spaceplane and merely represented another technological step towards total reusability.

USAF personnel were still pondering total reusability, however, in the shape of Aerospaceplane, a SSTO (Single-Stage-To-Orbit) vehicle that would be,

> "...of tremendous big winged design ... propelled from the ground horizontally by turbojets. The craft would carry liquid hydrogen and would scoop oxygen from the upper atmosphere which would be liquified. With fuel thus obtained ... the vehicle would be ready to penetrate space and then to return to the atmosphere for landing at an airfield."
>
> *Space Daily* July 18, 1962, p.75



(1) A-4b Winged Rocket

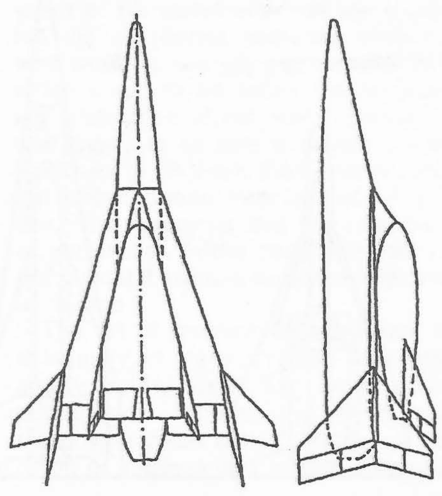
(2) - (4) Piloted "A" Variant

This project would have been virtually impossible to achieve in the early 1960s and it was no surprise when it was cancelled in 1963. DYNA-SOAR, by this time labelled X-20, was also shelved in the same year. US resources were being funnelled into the Apollo and Gemini programmes and the aerodynamic way into space seemed well and truly eclipsed by the tried and tested ballistic systems.

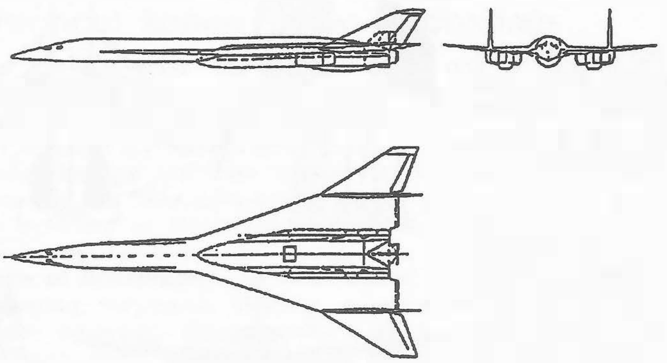
Europe

In Germany, however, Eugen Sänger was lobbying hard for Europe to develop a form of spaceplane, the Aerospace transporter. He worked with the Junkers company on a TSTO design as a precursor to an SSTO vehicle. Messerschmitt-Bolkow-Blohm (MBB) were also looking at a TSTO spaceplane.

MBB TSTO concept of the 1960's.



Work was going on in other European countries as well. In France, the Dassault company, in association with the French space agency CNES, proposed a small "Space Taxi" orbiter which would be launched at altitude from an aircraft.



Dassault/CNES TSTO Concept incorporating ventrally slung "Space Taxi".

Research was also carried out in Britain where a variety of partially and wholly reusable winged launchers were investigated during the 1960s. The best-remembered is the British Aircraft Company's Three-Stage-To-Orbit MUSTARD (Multi-Unit Space Transport and Recovery Device) which, while totally reusable, was launched vertically. This system was of particular interest to the Americans who, by the end of the 1960s, were once again thinking seriously about a totally reusable spaceplane.

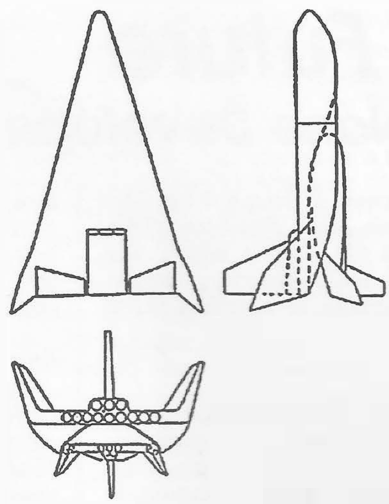
Reusable Shuttle

The US vehicle would form part of a Space Transportation System to supply and maintain an orbiting spacestation with a view to further interplanetary missions e.g. to Mars. This mirrored Sanger's philosophy from the 1920s and 1930s.

The AACB (Aeronautics and Astronautics Coordinating Board) had reported in 1966 with a suggested development timeline from partially to totally reusable launcher systems. In 1969, NASA invited US aerospace concerns to produce initial designs for a Shuttle.

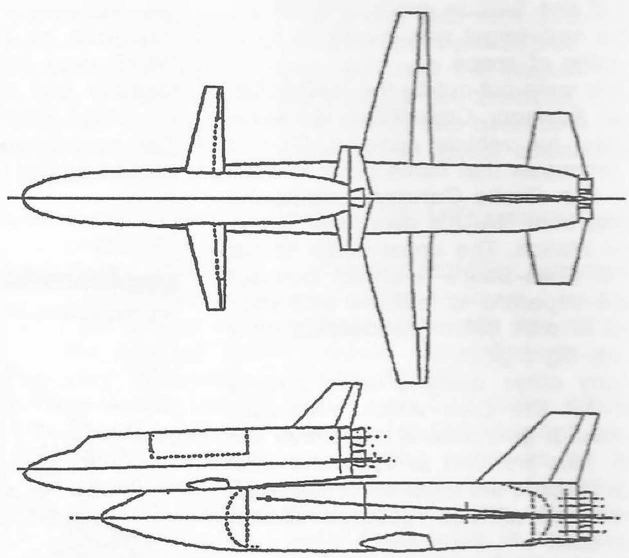
NASA's Langley Research Centre proposed a TSTO arrangement based on the HL-10 Lifting Body design. Both stages would employ airbreathing propulsion systems which draw oxygen from the atmosphere.

Another design which attracted a great deal of attention came from Max Faget of the Manned Spaceflight Center, Houston. This TSTO system comprised a huge winged first stage from which an orbiter, already resembling the eventual Shuttle, would be launched.



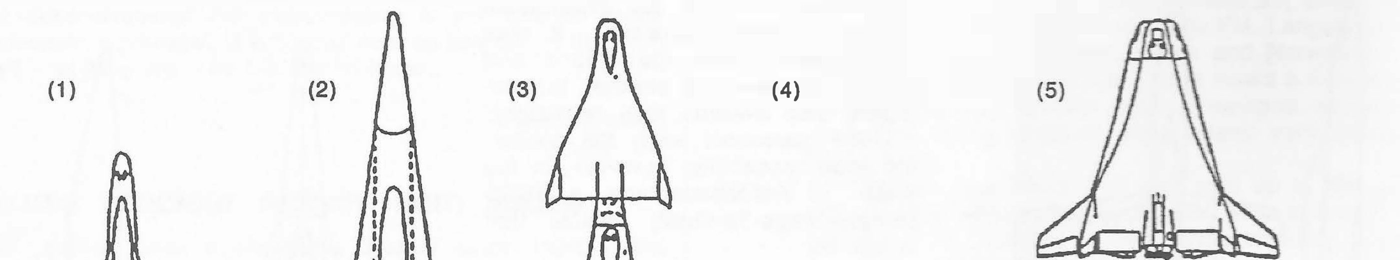
TSTO Shuttle based on Langley's HL-10 lifting body.

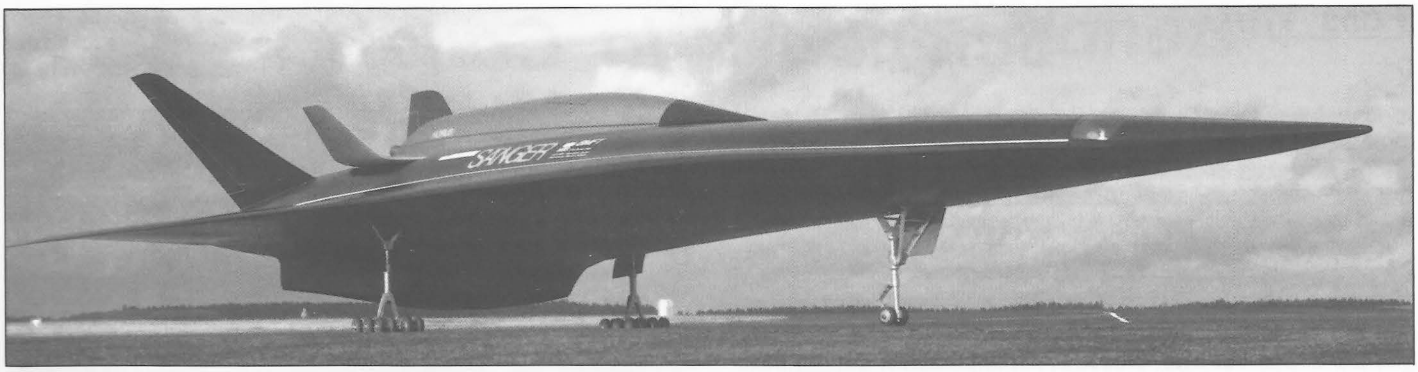
The second round of designs revealed some impressive looking TSTO vehicles from North American Rockwell and McDonnell Douglas. Total reusability was still the aim and it began to look as though the earlier visions of pioneers might at last be realised. Then the limiting factor of money appeared.



Manned Space Flight Center's TSTO Shuttle from Max Faget.

Partially/Totally Reusable Vehicles Reviewed by the British Aircraft Company: (1) Horizontal Take Off, Partially Reusable; (2) Horizontal Take Off, Reuasable; (3) Vertical Take Off, Reusable; (4) Vertical Take Off, Reusable (MUSTARD); (5) Alternative configuration for "MUSTARD".

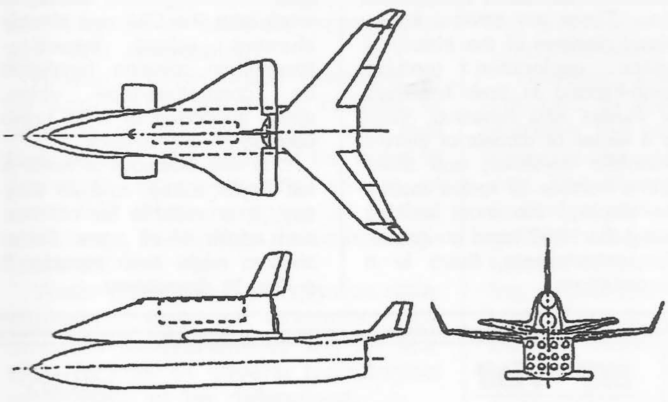




1:85 model of Sänger with HORUS. *MBB*

Partially Reusable

In 1971 the US Office of Management and Budget expressed its unwillingness to support NASA above its fiscal limit for the year of $3.2 billion. Any technological reservations with the latest round of Shuttle designs were amplified by this problem of insufficient funding and NASA eventually settled for a partially reusable Space Transportation System. The Shuttle, as we know it, was therefore conceived and ten years later Columbia was launched on its maiden flight. The wait for a true spaceplane continued.



Second round McDonnell Douglas TSTO concept.

HOTOL

In 1982 the British Interplanetary Society held a Space Transportation symposium. Amongst those attending were Alan Bond of the United Kingdom Atomic Energy Authority laboratories at Culham and Bob Parkinson of British Aerospace. They subsequently realised that the symposium had triggered complementary thoughts. Parkinson had drafted a SSTO horizontal take off vehicle while Bond had outlined an innovative hybrid airbreathing rocket engine which would propel it.

This spaceplane concept was known, at first, as SWALLOW but, more by accident than design, it eventually acquired the acronym HOTOL for (HOrizontal Take Off and Landing.

HOTOL was conceived as an unpiloted space plane capable of putting an 8-tonne satellite in a 300 km orbit. Proof of Concept studies were successful but progress was hampered by insufficient funding and a security classification which effectively prohibited alternative backing from overseas.

The original HOTOL is now in obeyance while an interim scheme is investigated. British Aerospace and the Russian Central Institute of Aerohydrodynamic research have been looking at a TSTO system in which a modified HOTOL is to be launched from an Antonov 225 aircraft. INTERIM HOTOL would use conventional rocket motors rather than the hybrid RB545 of the original.

Alan Bond is not connected with INTERIM HOTOL and is in the process of putting together his own consortium to support development of SKYLON, a new SSTO vehicle employing an improved hybrid airbreathing rocket engine.

Other Studies

The HOTOL public announcement at the 1984 Farnborough Air Show caused quite a stir and it was not long before other countries were following suit with their own spaceplane concepts. Some were new and other were dusted down and updated versions of earlier research programmes.

MBB unveiled their appropriately named SÄNGER, a TSTO spaceplane which would use turbo-ramjets on the first stage and rocket motors on the piloted orbiter. An alternative unmanned second stage was later abandoned.

Dassault resurrected their TSTO scheme from the 1960s as STAR-H. Following separation from the reusable first stage the second would use an expendable booster to achieve orbit. This would not therefore be a truly reusable spaceplane. Spaceplane research was also announced in the Soviet Union (which had been investigating an Antonov TSTO system before INTERIM HOTOL surfaced), Japan and India.

NASP

In his 1986 State of the Union Address, President Reagan referred to a new "Orient Express" which could cut the journey time from New York to Sydney to a couple of hours. He was talking of the National Aerospaceplane (NASP), a SSTO concept which, in reality, was still years away from a demonstrator vehicle, let alone a passenger-carrying space liner.

NASP was the most ambitious of the 1980s spaceplane projects. With a sizeable military function it had to follow particularly demanding flight profiles and this called for highly advanced propulsion, thermodynamic and control systems. It swallowed up huge amounts of research funding and, with the ever present financial constraints, there was no guarantee that Congress would even allocate sufficient money to build an X-30 demonstrator vehicle.

The Future

It is the question of money which once again seems likely to delay spaceplane development around the world. Many engineers will argue that vast sums do not have to be thrown at spaceplane research. David Ashford, for example, has devised an incremental approach to spaceplane design which makes maximum use of existing technologies.

Nevertheless, any long-term project requires considerable financial backing and the spaceplane proponents have, as always, to compete with many other causes. Perhaps, as we wait again, we must simply draw on the confidence of Eugen Sänger who said in 1925, "Nevertheless, my Silverbirds will fly".

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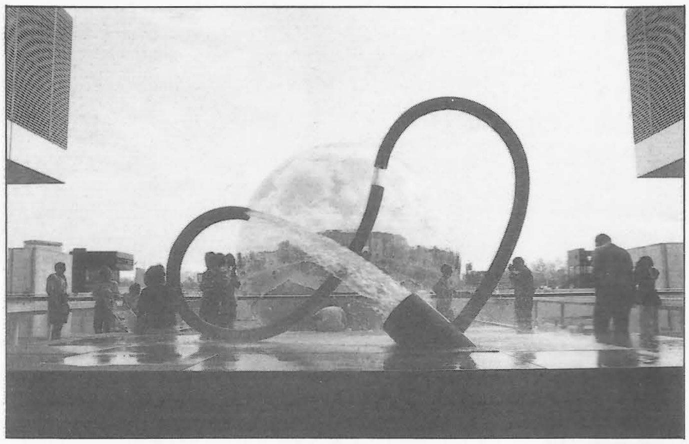
Paris Visit

Science à la Carte!

Brian Harvey **writes about a science museum in Paris that is well worth a day's visit. For space enthusiasts there is much to interest them.**

BY BRIAN HARVEY
Dublin

Most museum-going space enthusiasts think in terms of the lavish displays of the Smithsonian museum in Washington DC or the VDNK in Moscow. An impressive, though more modestly-sized space exhibition is now relatively close at hand in the futuristic Cité des Sciences et de l'Industrie (City of Science and Industry) in Paris, France.



Modernistic figure-of-8 water foundation, géode in background.
Photo supplied by author

Cité des Sciences is built on the site of the old Paris abattoirs to the north-east of the city. It is a large complex of glass-and-steel 40 m-tall 30,000 m² science museums, full of lifts, walkways, ramps, bridges and platforms. Cité des Sciences is about hands-on science: the format is learning through doing, seeing, touching and hearing. Visitors explore such diverse subjects as mathematics, optics, sound, robots, the world of microbes, computers and time.

Outside the main science building are two special attractions: the *géode*, a round cinema-roof 1000 m² projection building with several shows daily; and a French navy 1957 submarine, the *Argonaut*, which one can walk through accompanied by a headset commentary. The *géode* generally shows educational programmes, last summer's special being *Blue planet*, a spectacular and beautiful tour of the Earth through the eyes of the NASA space shuttle's IMAX-camera.

Two floors of the main science block are devoted to the space exhibition which is dominated, as one might expect, by France's national space programme and its cooperative ventures with other countries. There are excellent models of Ariane, Salyut 7, Freedom and Mir; and a lifesize exhibit of Spacelab with model astronauts at work on a typical mission. There are several audio-visual displays of the history of space exploration (notably even-handed in their treatment of Russia and America); there is a series of models of current scientific missions; and there are a number of rocket motors on display, the most striking being the HM-7 used on Ariane. For astronomers, there is a planetarium.

Although the Russian-French *Antares* manned mission had only just ended, a week later the Cité was already showing edited takeoff-to-touchdown mission highlights on continuous-tape video, amply supported by a full press dossier on the mission.

Cité des Sciences is worth a full day's outing, and as they say, it is suitable for children and adults of all ages. Some children might even consider it a rival to Eurodisney.

BIS Visit

British Telecom London Teleport Isle of Dogs

The Society is pleased to announce that, as part of its 60th Anniversary Celebrations, a visit for Society Members - especially those interested in Space Communicatons - will be made to BT London Teleport at the Isle of Dogs, London, on 31 March 1993 from 10:15 am to 2 pm.

London Teleport is on the North Bank of the Thames, adjacent to the Woolwich Ferry Terminal and 300 yards from North Woolwich Station on the Central Line

The visit will include:

- A Presentation on the Facilities
- A tour of the Complex which will include an opportunity to view a range of different types of antennae and associated Earth Station Equipment
- Complimentary Buffet Lunch and refreshments will be Provided
- Discussion session to follow after lunch

Registration forms and location maps are available from:
The British Interplanetary Society
27/29 South Lambeth Road, London SW8 1SZ

BIS Visit

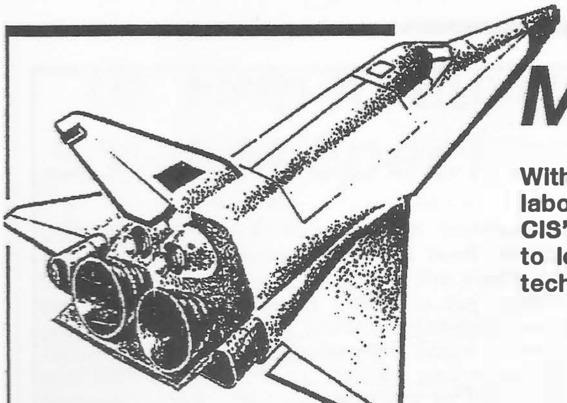
Royal Aircraft Establishment/Defence Research Agency

The Society is pleased to announce that, as part of its 60th Anniversary Celebrations, a visit for Society Members to the Royal Aircraft Establishment/Defence Research Agency at Farnborough, Hants has been arranged for 21 May 1993.

The visit will include a tour of facilities concerned with:

- Remote Sensing Imagery Produciton (Optical & Radar)
- Radar Systems Research
- Power Systems Technology
- Electric Propulsion
- Chemical Propulsion
- Small Satellite Programme (STRV-1a and 1b)
- Measurements of Space Radiation Environment
- Space Test Facilities
- Complimentary Lunch and refreshments will be Provided

Registration forms and location maps are available from:
The British Interplanetary Society
27/29 South Lambeth Road, London SW8 1SZ



MAKS Orbiter

MAKS - Eastern Promise ?

With the opening up of the former Soviet Union many opportunities to collaborate on major space projects now exist. One of the most exciting is the CIS's aerospaceplane project called MAKS, which offers a promising route to low cost flexible transportation into low Earth orbit. So the history and technical details of the project are of interest.

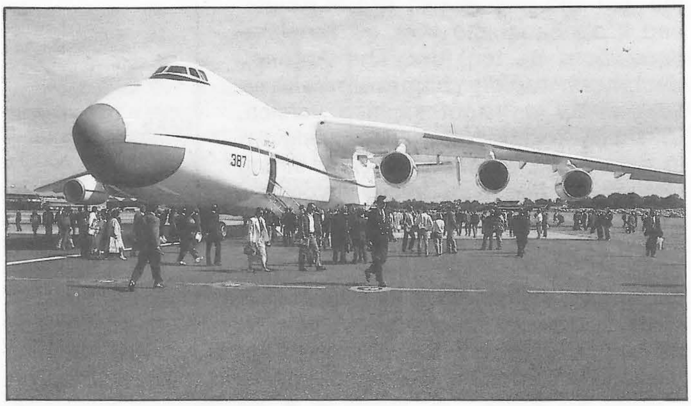
BY MARK HEMPSELL and **BOB PARKINSON**
BIS Council Members

At the Paris Air Show in 1989 the Soviet Union publicly displayed their massive An-225 carrier aircraft - the largest aeroplane in the world - carrying the Buran Space Shuttle on its back. Billed as a "heavy lift" aircraft it was capable of transporting the Buran Shuttle and components of the Energia launch system, or of carrying large and heavy payloads (chemical processing plants and even entire ships were mentioned) to remote sites by air. When a delegation from British Aerospace were shown around it, the first sight that greeted them as they entered the enormous hold was a poster showing the An-225 carrying HOTOL.

The An-225 design team had always seen one of its roles as a carrier for Single Stage To Orbit (SSTO) launch systems. Since its carrying capacity of about 275 tonnes matched the mass of the airbreathing HOTOL to within 5 tonnes, the Soviets were interested in discussing whether their aircraft could be used to replace the launch trolley; widely considered to be HOTOL's Achilles heel. The result of these discussions were joint studies between British Aerospace and the Soviet aerospace industry into the potential of the An-225 in the HOTOL concept.

Over the next three years a proposal called the Interim HOTOL evolved. This was a pure rocket version of HOTOL which, like the original airbreathing version, would be fully reusable and carry a payload of about 7 tonnes into orbit. It was called the Interim HOTOL because it was never intended to be a development instead of the airbreathing system. Rather it was seen as a way of still significantly improving launch costs by the year 2000 (the original goal of the project) despite the delays in starting the development of the airbreathing engine which meant it could no longer be ready in time to meet this target. The airbreathing system, which has always been seen as the best long term approach, could then be introduced later, bringing launch costs down still further.

Very early during the joint work with the Russian and Ukrainian engineers British Aerospace were introduced to the NPO Molnija design bureau in Moscow - who were responsible for the design of the Buran orbiter. NPO Molnija had their own project for utilising the huge lifting capacity of the An-225 as the basis for a reusable launch system, which they called MAKS (Mnogotselevaya Aviatsionno Kosmicheskaya Sistema or Multi-Purpose Aerospace System). MAKS was in an advanced state of design and although it did not meet all the HOTOL requirements it has been seen as an alternative route to low cost, on demand access to space.



Antonov 225 at 1990 Farnborough Airshow. *D. Millard*

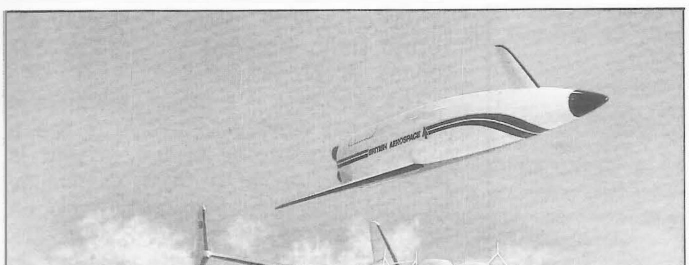
More recently other European countries have started to take an interest in the MAKS concept. With serious problems in the Hermes programme, the Council of Ministers have proposed "greater and deeper co-operation with Russia to arrive at a crewed space transportation system." Thus MAKS has become a serious contender as a collaborative replacement for Hermes.

An-225

The An-225 aircraft is a development by the Antonov design bureau which is located in Kiev in the Ukraine. It is an enlargement of the earlier transport aircraft - the An-124 "Russian" which was a Soviet equivalent of the American C-5A "Galaxy" military transport. The An-124 is actually about 5% bigger than the C-5A (making it the previous record holder as the world's largest aircraft) but looks very similar - a four engined, high wing, roll-on roll-off transport - and it had a very similar mission. An-124s are currently doing sterling work supporting emergency airlifts in various of the world's trouble spots.

At the moment there is only one An-225. It was constructed from a production An-124 by adding a new centre section to the wing, carrying two extra Lotarev D-18 engines, modifying the tail to a split fin arrangement, and adding a new centre section to the fuselage which takes the additional undercarriage to carry the massive 50% increase in size over its "smaller" brother! The way in which the An-225 is a modified An-124 is very clearly shown on the flight deck, where instruments for the engines are arranged in banks of four, with the extra dials for the extra engines added where space permits. With six throttle control levers in a row between the pilots seats, one feels a big pair of hands are needed to fly it.

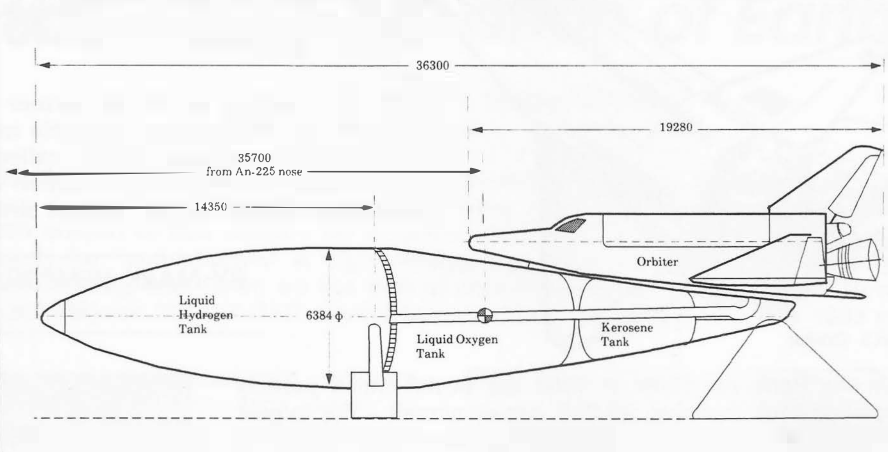
Artist's impression of INTERIM HOTOL launch from Antonov 225. *BAe*



The Antonov Bureau christened the An-225 "Mriya", which is Ukrainian for dream. It was, they said, big enough to carry anybody's dream. The name is very definitely

Ukrainian - the Russian alphabet does not even have a letter "i".

Although there is currently only one experimental An-225, it is clear that further aircraft can easily be constructed using components from the An-124 production line. Its potential is enormous. Not only does it have the capability to carry up to 275 tonnes, it has an impressive 10,000 km range to carry an unfueled MAKS or HOTOL to remote launch sites. As one example of its flexibility, when the HOTOL team wanted to design for operations out of the "hot and wet" launch site at Kourou and it appeared the take off acceleration would be too low. The Antonov designers rapidly came up with a scheme for an eight engined version, by simply podding the inboard engines in pairs - the wing was already strong enough for the extra forces involved.



MAKS Orbiter and External Tank

Prepared by British Aerospace Space & Communications Ltd

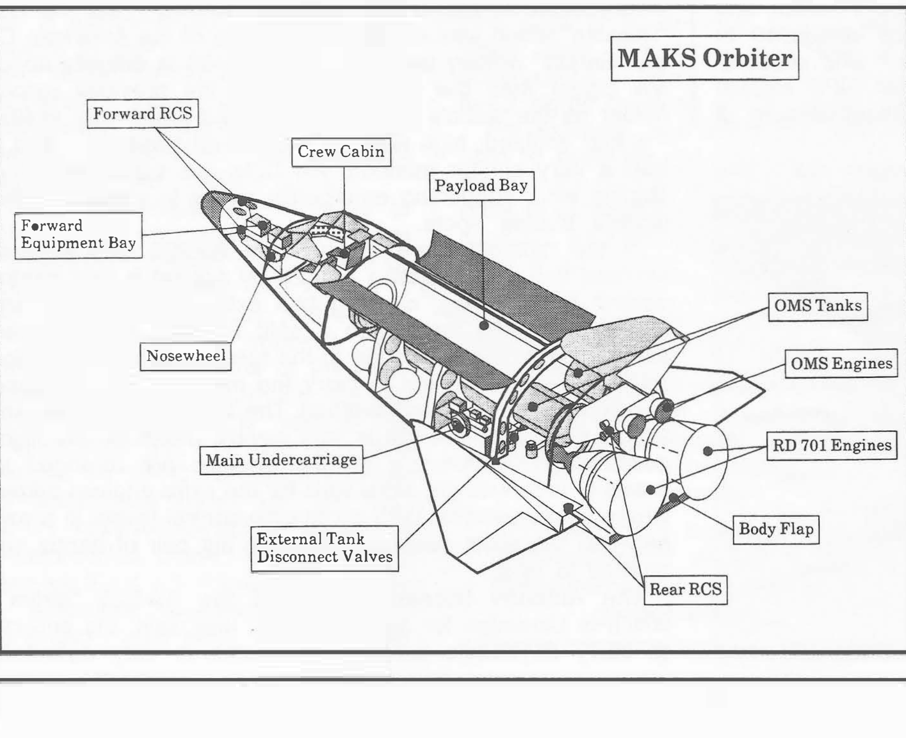
The An-225's suitability as a SSTO carrier is not just because it can carry a large payload. The detailed design is also intended for the role. It has suitable hardpoints on its back and provisions for many of the other systems needed for this task. This was partly to enable it to be a carrier aircraft for the Buran space shuttle, but also because it had been designed from the start as a launch platform for MAKS. This brings us to the history of the MAKS project

History

In 1982 the US Air Force had a proposal for an air launched Space Sortie System. This was a small reusable vehicle intended to be operated in much the same way as a military aircraft, and to perform "rapid access" missions to low Earth orbit with minimal payloads. The orbiter vehicle was to be carried aloft by a modified Boeing 747-200, and used a drop tank (with about two thirds of the propellant) and a winged reusable orbiter which carried the remainder of the propellants, engines, crew and payload. The Space Sortie System used "off the shelf" engines in the form of nine RL-10s as used on the Centaur stage. In addition a further seven RL-10s were installed in the tail of the 747 to augment the thrust and provide a high flight path angle for separation.

The Space Sortie System was seen as a way of providing an "on demand" small launch capability, operating out of conventional military airfields and capable of being launched into a variety of orbits at short notice. In theory the Sortie vehicle could have flown over any point on the Earth's surface within 90 minutes of take off. The winged orbiter would then have sufficient cross-range to land at a predetermined Air Force base within the USA. Unfortunately the carrying capability of the Boeing 747 restricted the system payload to about 3 tonnes into a 28.5 degree orbit and less than a tonne into a polar orbit (were the real military interest lay). With such a limited capability the idea died before it could be turned into hardware, like so many promising concepts before and since.

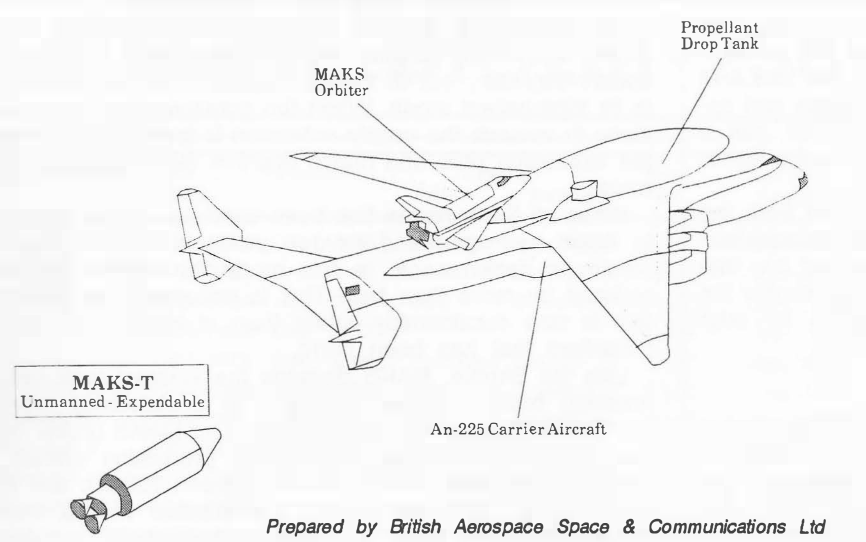
About the same time as the USAF was looking at the Space Sortie System, NPO Molnija started looking at a similar system based on the An-124. This was the birth of the MAKS project. Like the American study they found the concept technically viable, but the carrying capability of the An-124 restricted possible payloads to the point where they were too small to be of interest. In 1985 the study moved to considering launching from the new An-225 and the Council of Chief Designers approved development of the An-225 with one of the defined requirements being to carry MAKS. A little later work also started on a new engine for MAKS, the RD701, which is discussed later.



Vehicle

The current MAKS configuration has a 20m long winged orbiter and a single drop tank containing all the ascent propellant in an arrangement similar to the USA Space Shuttle. At separation from the An-225 the MAKS stack (orbiter plus tank) is 36.3 m long and weighs 275 tonnes of which 27 tonnes is the orbiter, 11 tonnes is the dry external tank, and the remaining 237 tonnes is propellant.

The drop tank is a major difference to the Interim HOTOL concept. It has a maximum diameter of 6.4 m and is largely manufactured from aluminium/lithium alloy. The forward hydrogen tank is separated from the oxygen tank by an insulated "common bulkhead" in a similar arrangement to that used on the USA Centaur and Saturn 5. The kerosine tank is in the rear of the elongated tear drop shape. Because the propellants are stored externally from the orbiter it is much smaller than the Interim HOTOL (see table). A conse-



Prepared by British Aerospace Space & Communications Ltd

quence of this is that the payload bay is much smaller than in the HOTOL concepts. It is 6.8 meter long and tapers from 3.0 m at the rear to 2.6 meters at the nose.

The NPO Molnija design team led by Chief Designer Gleb Lozino-Lozinsky plan three versions of MAKS. The manned version which would be used for crew transfer and other missions requiring manned intervention. The manned vehicle has a small cabin which carries a crew of two but it would be possible to add a passenger cabin in the payload bay to increase the crew size. The accommodation is much smaller than Shuttle, Buran, or even Hermes and is not intended to turn the orbiter into a mini-space station with long orbital flights. MAKS is seen as solely a transport system for payload and crew delivery and the maximum mission is only 5 days.

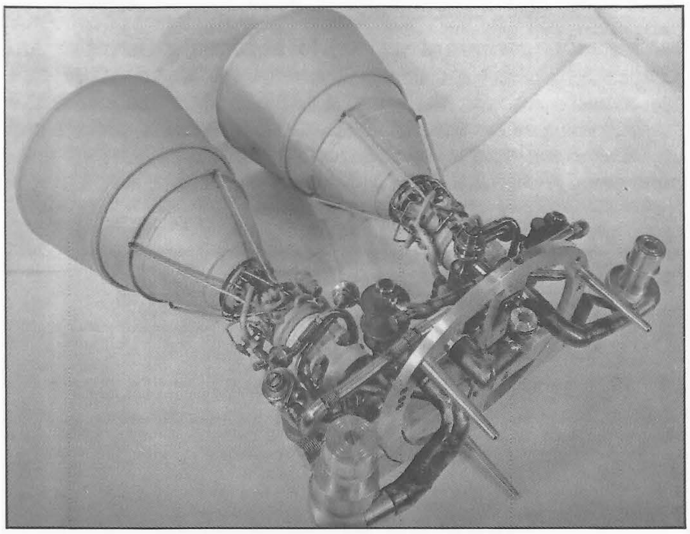
The unmanned version for delivery of cargo follows closely the HOTOL unmanned philosophy. However whereas HOTOL's approach was to add crew to a primarily unmanned system, the MAKS' approach has been to take the crew out of a manned system. This unmanned version would remove the crew cabin allowing the payload bay to be extended to 8.75 m and adding over a tonne to the payload mass.

A third totally expendable version of MAKS is also understudy called MAKS-T. In some respects this concept is reminiscent of the Shuttle-C proposals in that most of the systems are common with the reusable MAKS, but in this case all the hardware is thrown away. Although the cost per launch rises dramatically, the MAKS-T could place 16 tonnes into orbit, which is close to the performance of Ariane 5 and Titan III.

The technology used in the MAKS orbiter is described by NPO Molnija as "conventional" and uses the experience gained on the Buran shuttle. Their estimated payload is 8.5 tonnes for the manned version into a 200 km 51° orbit and 9.5 tonnes for the unmanned version. These estimates may be a little optimistic, but it is clear that there is considerable commonality in a number of key technology areas with the ESA work on Hermes, and a joint CIS/ESA programme would have some confidence in achieving very competitive payload masses.

Engine

While originally a conventional oxygen/hydrogen vehicle the MAKS designers discovered that the performance of the vehicle would be very significantly improved by using a tripropellant system. As a consequence a new engine development was started with the unique feature of being able to burn three propellants together in the same combustion chamber. The engine is designated the RD-701 and has been under active development by the NPO Energomash, under its general director Boris Katorgin, since 1988. The MAKS orbiter has one of these engines mounted in the rear engine bay.



RD701 tripropellant rocket engine mock-up.

Energomash is based in a Moscow suburb called Khimky and produces the RD-170 a four chambered oxygen-kerosine engine used on the Energia boosters and the RD-171 derivative used on the Zenit launch system. The experience gained on the engines was exploited as a basis for the RD-701.

The RD-701 is a twin chambered engine (i.e. it has two separate nozzles) capable of operating as an oxygen-hydrogen-kerosine engine (Mode 1) for high thrust, or a pure oxygen-hydrogen engine (Mode 2) for high performance measured by specific impulse. As with all modern CIS rocket engines the RD-701 uses a "closed cycle" in which exhaust from the pump turbines is fed into the main chamber for increased efficiency. Each chamber has two pumps feeding it, one pump supplies both the kerosine and liquid oxygen and the other the liquid hydrogen.

RD-701 Performance

		MODE 1	MODE 2
Vacuum Thrust (kN)		2 x 2000	2 x 785
Vacuum Specific impulse (N sec/kg)		4071	4532
Launch* Specific impulse (N sec/kg)		3885	-
Flow rates	LOX (kg/s)	2 x 388.4	2 x 148.5
	LH2 (kg/s)	2 x 29.5	2 x 24.7
	Kerosine (kg/s)	2 x 73.7	-
Expansion Ratio	(Extension down)	170	170
	(Extension up)	70	-
Chamber Pressure (bar)		300	150

* 10 km altitude - Nozzle extension up

Another interesting feature of the RD-701 is its use of a deployable nozzle extension which is lowered into place when the engine is in near vacuum to increase the performance. This increases the engine length from 3.8m to 5.4 m and gives an exit diameter of 2.4 m. When in place and operating in the oxygen-hydrogen mode the RD-701 has a specific impulse of 4532 N sec/kg; some 100 N sec/kg higher than the US Space Shuttle main engines.

As with the US Space Shuttle the engine is fed from the external tank, via fast acting couplings on the undersurface of the orbiter, through into the rear of the payload bay into the engine's feed pumps. Also like the US Space Shuttle the orbiter has integral orbital manouvering engines for orbit injection, rendezvous, and reentry manoeuvres.

Mission

The launch process starts with the MAKS Orbiter being integrated to the external tank. The payload is then installed within the payload bay and the complete Orbiter/tank assembly is then lifted onto the back of the An-225. The propellants are loaded into the external tank just before take off.

At the end of the runway the whole assembly weighs 620 tonnes. After a conventional aircraft take off, the An-225 carries MAKS to an altitude of between 9 km and 10 km with an airspeed of Mach 0.8 (240 m/s). Up to one hour can elapse between take off and the launch of the MAKS orbiter. In this time the An-225 can travel up to 750 km from the airfield. This gives wider range in flexibility in launch time and inclination than a fixed launch site.

The separation manoeuvre is a delicate one. The MAKS vehicle must perform a pull up to separate it from the An-225, and light the rocket engine without damaging the carrier aircraft. As with the Interim HOTOL it is likely that the An-225 will perform a powered dive manoeuvre with a pull up, at the moment of separation. Although by way of contrast the US Space Sortie System proposed another approach of climb and "push over" to separate.

At ignition the engines must provide maximum thrust driving the MAKS vehicle, which is heavy with fuel, into an ascent trajectory out of the atmosphere. So the RD-701 is in its tripropellant mode. When the pressure has dropped to close to vacuum the nozzle extension is lowered to increase the expansion ratio and hence improve the engine performance.

When all the kerosine has been used the engine switches to liquid hydrogen and oxygen mode and is working at maximum performance. In this mode the engine thrust is reduced by more than half. This is acceptable as the system is now considerably lighter than at launch due to the propellant that has been burnt.

Like the Shuttle, MAKS discards the external tank before reaching orbital velocity, leaving it to destructively reenter the Earth's atmosphere and burn up. The MAKS orbiter then uses the smaller orbital manouverlng propulsion system to reach its final orbit, which can be between 200 km and 800 km altitude. After performing the mission MAKS would perform a deorbit burn, reenter the atmosphere, and then, like the Shuttle, it would glide down to a runway landing at the launch site.

For a typical "transport and maintenance" mission to a space station such as Mir, MAKS would carry a rendezvous system, a "Mating Module", and a pressurized cargo compartment. The Mating Module would be mounted in the payload bay immediately behind the crew compartment. In addition to connecting the crew cabin and cargo compartment, it would carry an expanding adapter tunnel with the docking interface on it. This would be the connection to the space station. The Mating Module has an internal volume of 3 m^3 and the cargo compartment a volume of 20 m^3. If additional crew were required the pressurised cargo compartment would be replaced by a passenger module. MAKS could also carry a manipulator similar to the Shuttle Canadarm or the Hermes HERA system.

Other mission for MAKS could included satellite deployment, conducting non deployable experiments, reconnaissance (military and civil) and satellite repair or recovery.

Programme

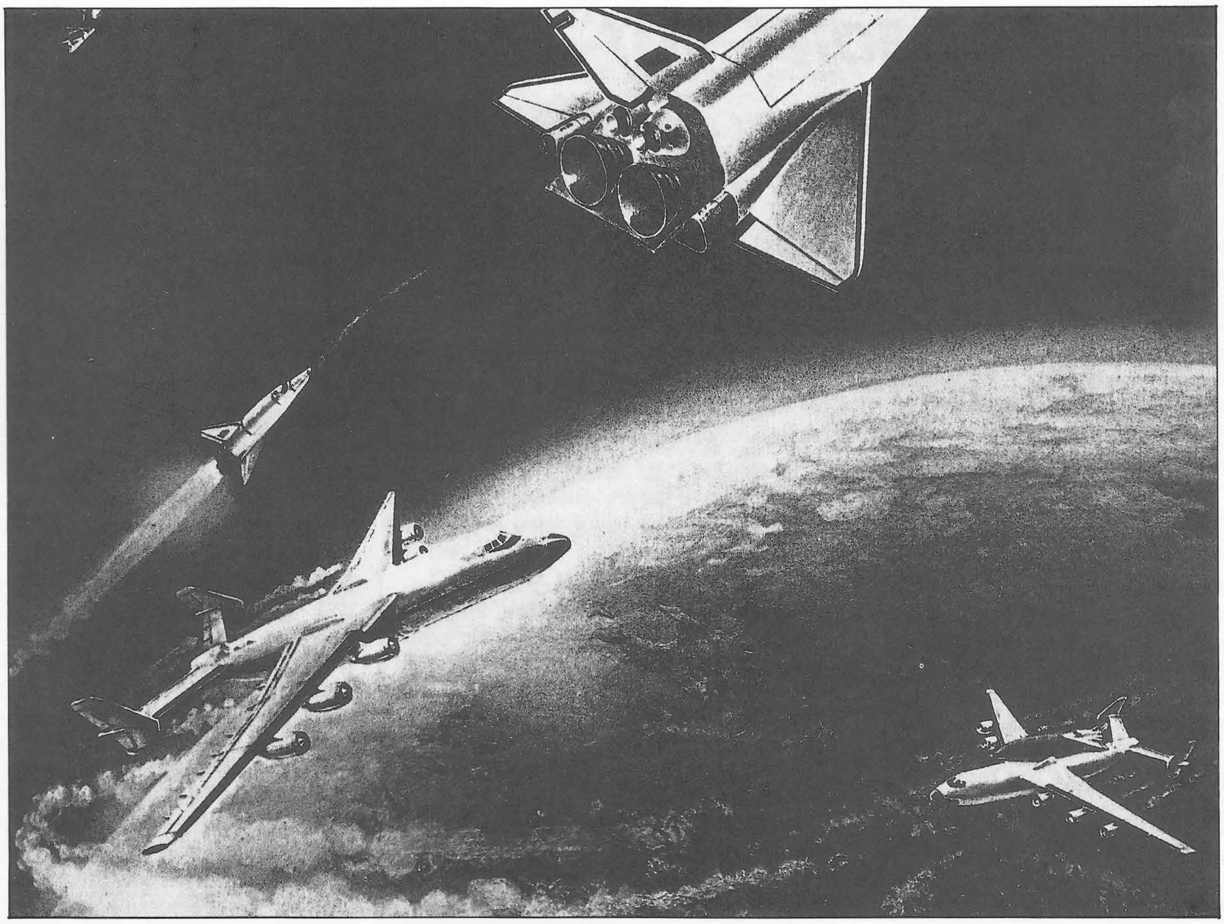
Since 1982 NPO Molnija have made considerable progress on the concept. The An-225 has flown and proven its performance. The RD-701 is 25% of the way through its development, and engineering mock ups have been made (see figure). MAKS structural models for strength and interface evaluation and a cockpit mock up for human interaction analysis have also been constructed.

Overall there has been considerable progress on MAKS development and NPO Molnija believe that a properly funded programme could achieve a first flight in 1997 with the system operational by 1999. This would meet the original intention of the HOTOL programme to get a reusable launch system with low cost on demand access to space in operation before the end of the century.

The NPO Molnija estimate the development costs at around 3.5 billion ESA accounting units (au). British Aerospace using West European costings estimated 6.2 billion au for the total programme. This difference is interesting in that it highlights the lower costs in the CIS. This is partly the lower labour costs, but is also a measure of the more efficient project management methods used. A joint ESA/CIS programme would probably cost somewhere between these two estimates, although it is to be hoped that ESA nations can absorb some of the cost effective project methods of the CIS approach, rather than inflict its expensive methods on to the CIS.

The Future?

There are now two proposals (Interim HOTOL and MAKS) based on the An-225 that would meet the HOTOL project objective to achieve low cost on demand delivery into orbit before the year 2000. So which is the best way forward?



Artist's impression of the MAKS system in operation.

Interim HOTOL would have the better cost performance. Its payload mass is very similar to MAKS, but the payload bay is larger and compatible with other launch systems such as the Shuttle and Ariane. It would also have lower operational costs due to simpler ground handling and its total reusability. British Aerospace estimate each interim HOTOL flight will cost 10.3 million au.

MAKS launches will be more expensive; British Aerospace estimate 12.8 million au per launch. MAKS advantage is the lower development cost which is between 3 - 4.5 billion au to complete the project, compared with the British Aerospace estimate of 6.8 billion au for the interim HOTOL. This lower development cost is in part due to its less ambitious technology and also the very large investment the CIS has already made in the vehicle.

The question of best approach then centres on whether the lower operational costs of the interim HOTOL can repay the higher development costs. This depends on how long the system is expected to be in operation and to answer that question requires planning of when the advance airbreathing launch system is to be operational.

However it is not only the HOTOL team that are likely to be interested. MAKS is also very similar in overall performance to the early Hermes (1985 vintage) when it had an external payload bay and was intended for a real infrastructure role. The technologies required by MAKS are also very similar to Hermes. So MAKS may prove a more practical and cheaper route to realising the Hermes goals. Given MAKS could go some way to meeting both British and continental European infrastructure objectives it makes an interesting candidate for CIS-ESA cooperation.

It is clear MAKS represents a unique opportunity for Western European nations to recover the lost momentum of their infrastructure programmes. While it does not completely satisfy either the British "economic capability" thinking typified by HOTOL, or the French "prestige and technology" thinking typified by Hermes, it is a workable compromise between the two. Thanks to the efforts the CIS have already made, it can be put in place quickly and comparatively cheaply.

However to start a joint ESA/CIS project and to carry it through to a successful conclusion, avoiding the problems afflicting Hermes and Columbus, will take a much clearer vision of the purpose of space within Europe and better management within the western European space industry. Without such a new start the promise of MAKS will almost certainty never be realised.

Comparison of MAKS, Interim HOTOL and Hermes.

	MAKS Orbiter	Interim HOTOL	Hermes
Length (m)	19.3	36.5	18.6#
Wing span (m)	12.5	21.6	9.0
Launch mass (less payload) (tonnes)	18.4	31.5	21.4#
Payload mass (tonnes)	8.5##	7	3
Payload bay diameter (m)	3 to 2.6	4.6	None*
Payload bay length (m)	6.8	7	None*
Crew	2**	0†	3

Includes expendable Resource Module
Unmanned version 9.5 tonnes
* Hermes payload is carried within the pressurised cabin and Resource Module
** Unmanned versions and passenger carrying versions also under study
† 4 to 6 people would be carried in the manned version

'On Console' for 14-Day Mission

Huntsville Operations Control Center in Action

As an assistant to the Mission Scientist, *Dale M. Kornfeld* worked at the Mission Scientist console position in the Payload Control Room M-203 at Marshall Spacelab Mission Operations Control during the 14-day STS-50 United States Microgravity Laboratory-1 (USML-1) shuttle mission. He writes for *Spaceflight* about the impressive team support organisation at the NASA Marshall Space Flight Center in Huntsville that swings into action during each shuttle Spacelab mission.

Huntsville Spacelab Mission Operations Control Center. From Left: Ann Bathew (DMC), James Downey, Dale Kornfeld (Assistant MSCI) and Don Frazier (MSCI).

BY DALE M. KORNFELD
Alabama, USA

The Payload Control Room M-203 is called the "front room" because the main cadre team leaders are located there and the NASA Public Affairs Office TV cameras broadcast views of us sitting at these consoles. There are several other payload support "back rooms" at MSFC, where the rest of the team members sit at their consoles (but no TV cameras), plus the Science Operations Area rooms where all the Principal Investigator teams man their consoles.

Personnel Organisation

The Mission SCIentist (MSCI) is leader of the PI (Principal Investigator) science experiment teams. For USML-1 it was Dr Don Frazier. The MSCI manages all science-related activities during all phases of the shuttle mission, approves all science inputs to the flight timeline, directs all science meetings and mediates any PI conflicts concerning science and on-board resource requirements. He reports directly to the Marshall Payload Operations Director. The POD is chief of all payload cadre at Marshall and is the counterpart of the Flight Director at Houston.

STS-50 USML-1 Mission Payload Operations.

Our Mission Scientist Team monitored on the console every step of every experiment as it was being conducted by the crew. We worked with all the Principal Investigator Teams to help resolve experiment anomalies and interfaced between them and the other MSFC cadre when necessary to reschedule activities.

An Alternate Payload Specialist sat nearby and worked with us on each shift. The APS is a trained alternate crewmember who would have flown if a primary crewmember had had to drop out. He assisted the Mission Scientist team, PI teams and other cadre on crew science and hardware procedures and overall Spacelab operations.

Dozens of additional support people are involved at MSFC, without which we could never have a successful shuttle Spacelab mission. All the PI and cadre teams are located at Marshall and are involved strictly with the Spacelab module and science experiments whereas the function of those at Houston is to monitor and control the Shuttle itself after launch from Kennedy Space Center.

The 14-day USML-1 flight was the longest Shuttle mission to date and we can now say that it was the most perfect shuttle science mission ever flown. The Mission Scientist and two Assistants manned our consoles during each shift for 15 straight days. We had our "call-to-stations" and went on console two days before launch but were released early on the last day, after all science operations had been completed and when the landing was postponed a day due to rain at Edwards AFB. The seven member astronaut crew divided into two 12-hour shifts, Red and Blue, in order to work around the clock during the whole mission. I worked mostly the Red Shift.

The entire Huntsville and Houston mission cadres and the flight crew trained as a group during a long series of sims which began in December 1991. Sims are one or two-day mission simulation exercises on the consoles, with the crew working in the Huntsville Payload Crew Training Complex (PCTC) Spacelab simulator. The mission went a lot smoother and easier than any of the sims, since during each sim all sorts of awful things are programmed to happen to the hardware, shuttle, or experiments, in order to train the crew and all of us to respond to malfunctions. It became apparent soon after launch that this was not just another sim, because everything was actually working great. The launch phase and all Spacelab module and experiment activations proceeded perfectly and our job was not very hard. The only minor hardware glitch was when a microswitch failed on the new carbon dioxide air scrubber system but the crew quickly fixed it and it ran perfectly for the rest of the mission.

Working this mission as a cadre member was quite a change from my usual laboratory research and now that it is over I can look back and say it was a lot of fun. However, during training (with all those awful sims) and while the mission was underway, it was a pretty intense experience.

Just about everything planned during the entire mission was accomplished and some extra experiments and activities were performed beyond what was scheduled.

Cadre Teams Located at MSFC

Operations Controller Team: composed of the Operations Controller, Crew Interface Coordinator, Payload Systems Engineer, Crew Procedures Engineer, Mass-memory Unit Manager and PAYload COMmunications Manager;
Payload Activity Planning Team: composed of the Payload Activity Planner, TimeLine Engineers, ORBITal analysis Engineer, and Payload Replanning Engineer;
Data Management Team: composed of the Data Management Coordinator, Data REPlanner, Data Flow Analyst and TV OPerationS.

SPACE SHUTTLE: STS-53

Last Mission with Classified Payload

Landing Diverted to Edwards AFB

Together with a classified Department of Defense primary payload, Space Shuttle Discovery also carried two secondary payloads and a number of middeck science experiments. The secondary payloads included studies of Shuttle glow phenomena, cryogenic heat pipe development and detection of simulated orbital debris. Middeck experiments studied the potential to produce pharmaceutical microcapsules for medicine and physiological studies.

BY ROELOF L. SCHUILING
At the Kennedy Space Center

Although this mission was Discovery's fifteenth flight, the orbiter had not been in space since January 22, 1992 when it returned from mission STS-42. Since then 78 major modifications have been carried out on it, the most significant being the addition of a parachute drag for landing, and the capability for redundant nose wheel steering. The orbiter also underwent a number of inspections.

In late July the three main engines were installed on Discovery with main engine 2024 in the number 1, or centre, position with engines 2012 and 2017 in positions 2 and 3.

Also in late July and August the unclassified secondary payloads GCP (Glow and Cryogenic Heat Pipe) and ODERACS (Orbital Debris Radar Calibration Spheres) were installed. Discovery's primary payload was a Department of Defense payload which was installed at the launch pad.

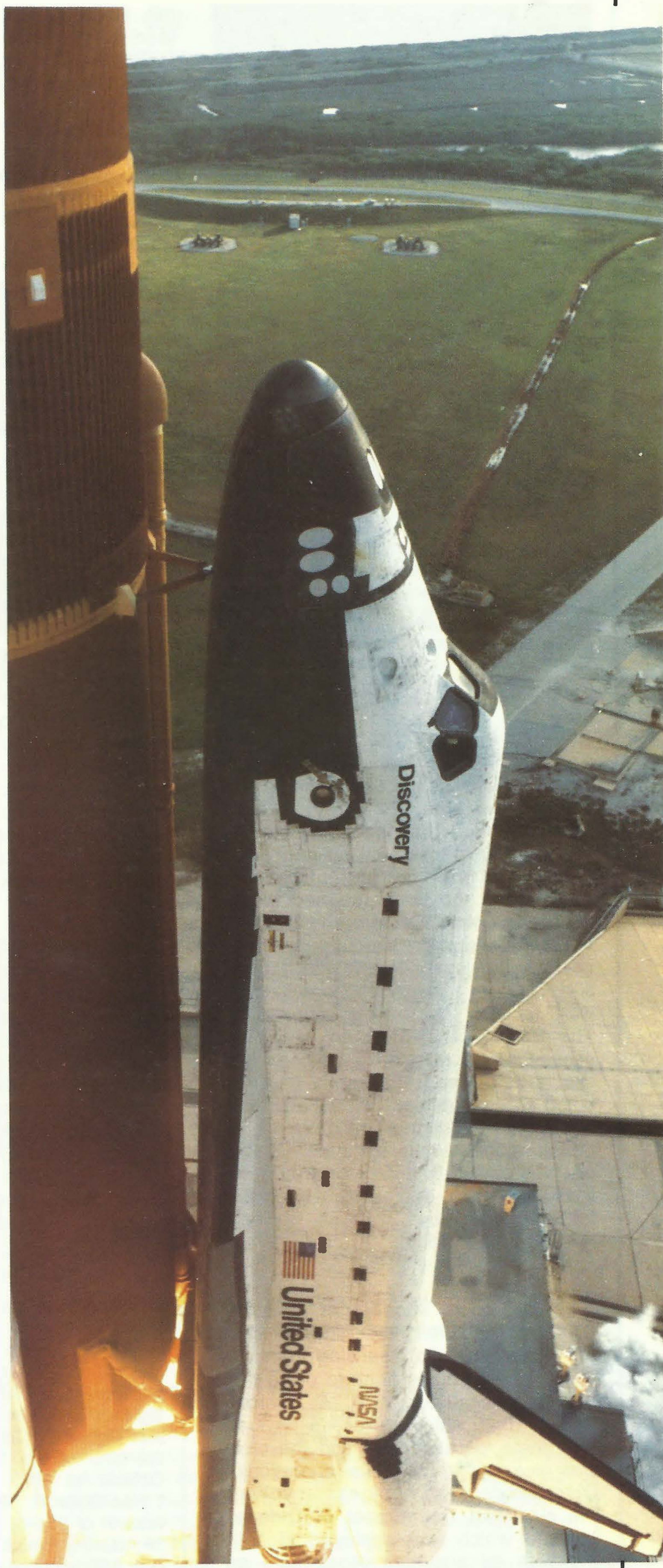
On November 3, Discovery was transported to the Vehicle Assembly Building, where it was rotated to a vertical position and mated with the External Tank and two Solid Rocket Boosters. On November 8, the completed Shuttle vehicle was rolled out of the Vehicle Assembly Building and out to Launch Pad 39A.

While at the launch pad Discovery underwent a simulated countdown, received its primary payload on November 19, and loaded hypergolic propellants for its manoeuvring system and reaction control system engines.

On November 30 the launch countdown was picked up 3 hours early to give extra time for fuel cell cryogenic reactant operations. The countdown proceeded without major impact until an extended hold at T-9 minutes on December 2.

The launch had been scheduled for 6:59 am that morning; however, cold weather delayed the launch until 8:24 am. Temperature overnight had dipped to 47 degrees and a coat of ice and frost had accumulated around the cryogenic propellant areas of the External Tank.

With sunrise scheduled to occur at 6:58 am, mission managers elected to continue with the countdown and then to extend the built-in hold at T-9 minutes. The hold was extended for an hour and twenty-five minutes during which period the Kennedy Space Center's Ice Evaluation Team went to the launch pad to monitor the ice buildup on the tank. The Ice Evaluation Team monitors the Shuttles on each launch to insure that no hazard from ice buildup is present. The concern of the launch team is that should an ice buildup be shaken loose at launch, some ice debris could hit the



The Space Shuttle Discovery soars into a cloud-studded sky from the Kennedy Space Center's Launch Complex 39A on December 2, 1992 at 8:24 am. It carried a crew of five, a classified Department of Defense primary payload, two secondary payloads and a varied complement of middeck science experiments. Cold weather delayed the launch by 2 hours 25 minutes.
NASA

Pilot Robert D. Cabana (front, left) and Commander David M. Walker (front, right) lead the way from the Operations and Checkout Building, enroute to the Space Shuttle Discovery at Launch Pad 39A. Behind them are Mission Specialists Michael "Rich" Clifford (left), Guion S. Bluford, Jr, and James S. Voss. The crew is all-military: Cabana, holding the "Beat Army" banner, is in the Marine Corps; Clifford and Voss are Army. *NASA*

Shuttle's thermal protection tiles and damage them. As the Sun came up and warmed the area, the Ice Evaluation Team reported that the frosty coating was melting. After about an hour, they determined that no further concern existed and the team returned to the Launch Control Center.

The countdown picked up and proceeded flawlessly to the liftoff point and Discovery began its ascent northward to a 57 degree inclination orbit. The Solid Rocket Boosters cutoff on schedule at 2 minutes 4 seconds into the mission and the main engines cutoff at 8 minutes and 42 seconds into the flight. Following the burn of its orbital manoeuvring engines, Discovery was placed in a circular orbit at an inclination of 57 degrees and height of 200 nautical miles with all systems operating normally.

Flight Day One

Following its successful liftoff at 8:24 am (all times KSC time) Discovery performed a circularising manoeuvring system engine firing to place it in a 200 nautical mile orbit. At approximately 10:00 am the orbiter's payload bay doors were opened and the crew was given a "go for orbital operations". Discovery's first business involved the classified Department of Defense payload which was deployed at 2:18 pm with all activities proceeding as planned. Mission commentary, television and Space Shuttle-ground communications were then resumed.

The crew activated several secondary experiments, including the Cosmic Radiation Effects and Activation Monitor (CREAM) and the Radiation Monitoring Equipment (RME), which made complementary measurements of the radiation in the crew cabin. The crew also began medical tests which are performed on many Shuttle flights to study the effects of weightlessness. These involved photography of the retina and measurement of pressures within the eye.

Discovery's crew activated the Glow Experiment/Cryogenic Heatpipe (GCP) payload which is a Hitchhiker programme payload from the Goddard Space Flight Center where their experimental data were received after being removed from the Shuttle's downlink data stream at Mission Control.

Flight Day Two

The morning was spent working with several experiments and making Earth observations from the 57-degree inclination orbit. The crew activated the hand-held Earth-oriented Real-time Cooperative User-friendly Location-targeting and Environmental Systems (HERCULES) experiments, a modified camera system designed to enable an astronaut to precisely determine the latitude and longitude of terrestrial features as they are being photographed from orbit. This was the first HERCULES flight. Sites observed included Eleuthera Island in the Bahamas, Minch Peninsula in Denmark and Galveston Island, Texas.

The Battlefield Laser Acquisition Sensor test (BLAST) uses a laser receiver to detect laser energy from ground-based locations to provide data for the development of sensor technology for laser communications. BLAST was activated but the two opportunities on this day were unsuccessful due to ground site problems.

The Fluid Acquisition and Resupply Experiment (FARE) was used to investigate the physics of fluid transfer in microgravity. Such information is needed to plan operations involving fluid replenishment on long-term space missions such as the Space Station and the Extended Duration Orbiter flights.

Later in the day the crew performed two manoeuvring system engine burns to reduce altitude from 200 to 175 nautical miles. The reduction was in preparation for the release of a series of metal spheres planned for the following day.

Flight Day Three

The crew had planned to release six spheres from the Orbital Debris Radar Calibration Spheres (ODERACS) experiment on this day. The spheres were in two sets of three with one set of aluminium and one of stainless steel. Each set comprised a two, four, and six-inch diameter sphere. The purpose of the experiment was to provide known targets for the calibration of ground-based radars used to study orbital debris. The release had been planned for 6:22 am. However, about ten minutes before the planned release the crew reported they were not getting good signals through the deployment system electronics. The system was rechecked and the crew attempted to use a second input location to the ODERACS electronics but the expected response from the experiment was not received. The 20-minute deployment window was passed without success and the experiment attempt was terminated as ground controllers began an analysis to determine the probable cause of the problem. The next deployment opportunity would not come until Flight Day Five. Later in the day the crew used a test kit from the standard Shuttle tool kit equipment to verify connections in the cabin.

Flight Day Four

The crew continued work with the secondary payload experiments during the day. Later in the day, after considerable analysis, ground controllers passed the word to the crew that the decision had been made not to attempt any further ODERACS deployment activity. Their analysis indicated that the most likely problem was a dead battery within the payload bay-mounted experiment. The decision was based on the review of manufacturing, ground processing and in-flight data; however it would be impossible to verify that conclusion until after the mission had landed.

Flight Day Five

The Discovery's crew continued a variety of scientific and engineering studies on their fifth day in space and also took time out to hold an in-flight press conference with reporters on the ground at NASA Centers.

Landing weather predictions of possible marginal conditions

STS-53 Crewmembers

Commander of the five man crew was David M. Walker who served in the same capacity on Mission STS-30 in May of 1989. Walker was also the pilot on STS-51A, his first space flight, in November of 1984. The pilot was Robert D. Cabana who was also the pilot of the STS-41 mission in October of 1990. Mission specialist 1 was Guion S. Bluford Jr who was a veteran of STS-8, STS-61A and STS-39; during which he accumulated over 500 hours of space flight. James S. Voss was mission specialist 2 and had flown on STS-44 in November of 1991. Michael R. Clifford, mission specialist 3, was making his first flight.

At Launch Pad 39A, the white room closeout crew helps STS-53 Mission specialist James S. Voss (left), Michael "Rich" Clifford and Pilot Robert D. Cabana prepare to enter the cockpit of the Space Shuttle Discovery, awaiting liftoff at 6:59 am, EST. *NASA*

prompted a request from Mission Control that the crew power-down non-critical equipment to save electricity. This would add to the Discovery's power margins in the event that the flight might have to be extended beyond its current reserves. The amount of electricity available aboard a Space shuttle is related to the usage of cryogenic hydrogen and oxygen in the electricity-producing fuel cells. Reducing the power usage prolongs the reserve of those reactants.

Flight Day Six

It was a busy day for the crew as Guy Bluford, Jim Voss and Rich Clifford performed secondary payload experiment operations including HERCULES and BLAST data takes, visual function tests, and an experiment designed to produce pharmaceutical microcapsules in space. The microcapsules contained ampicillin and would later be compared with ground-produced ampicillin microcapsules for comparison.

The day's activities included a Flight Control System checkout to verify the mechanical and hydraulic systems which are required for the shuttle's landing. This checkout also verified displays and sensors used by the crew during landing. In addition the crew performed a test of the Reaction Control System with a thruster firing test. Checking out orbiter systems in preparation for landing is usually performed on the day prior to landing; however on STS-53 it was moved up one day to provide uninterrupted data gathering for the GCP glow experiment on the day before landing. Due to the launch time, the day, and the high inclination orbit parameters, Discovery had not spent the time in darkness required for the final day's test until December 8.

Following these operations, an orbital manoeuvring system burn was performed to lower Discovery's orbit and set up an additional possible landing opportunity for the KSC runway due to the predicted marginal weather conditions at the planned landing time.

Flight Day Seven

Much of the crew's activity involved studies of the Glow effect in a night environment. Onboard thrusters were fired and data were also taken during fuel cell purge and overboard water dumps to determine the effects of these activities on the fluorescent effect created as the Shuttle encounters atomic oxygen in orbit.

The secondary payload activities were completed and the equipment stowed for landing. FARE completed its eighth and final run. HERCULES was stowed after having taken more than 200 photographs, eight times as many as planned. BLAST had completed 20 attempts to send laser information to orbit; however poor weather and ground equipment problems allowed only two receptions by the Shuttle equipment and further analysis will be done on the system.

Other experiments involving radiation studies, analysis of tissue loss, studies of cloud fields from orbit ad visual function test equipment were stowed in preparation for landing.

Before going to sleep, the crew performed a small two foot-per-second thruster jet burn to avoid a piece of space debris.

Flight Day Eight

After final preparations for the planned Kennedy Space Center Landing were completed the mission was diverted from KSC due to cloud cover. The STS-53 mission ended with touching down on the Edwards Air Force base, California after 7 days, 7 hours, 19 minutes and 19 seconds of space flight. Discovery's main gear touched down on runway 22 at 3:43:17 pm Florida time on December 9, 1992 (local California time was 12:43:17 pm). Nose gear touchdown was at 3:44:04 and wheel stop at 3:45 pm.

The crew departure from the orbiter was delayed due to a leak in one of the orbiter's nose thrusters. Ground personnel performed extensive checks to insure that no danger to the crew was present before the hatch was opened and the crew left the orbiter an hour and a half later than planned. Later that day the Discovery began preparations for its return to florida aboard the Shuttle's 747 ferrying aircraft.

Shuttle: Prelude to Space Station Work in 1993

With the launch of the first element of Space Station Freedom just three years away, NASA will continue to use the Space Shuttle fleet in 1993 for research associated with Space Station assembly and operations.

The space station programme is on schedule to complete its first Critical Design Review (CDR) in June. The CDR marks a commitment on the part of the space station programme managers to proceed from the design stage to the fabrication and acquisition of flight hardware and software. The CDR includes the review of thousands of engineering drawings and other design documents by NASA and contractor personnel.

Beginning with the first Shuttle flight in January (see p.96 for a report on STS-54) and ending with the eighth mission in December, astronauts will conduct spacewalks, materials and life sciences research and small-scale experiments to prepare for long-duration stays in space aboard Freedom. Spacewalks will be conducted on at least three flights in 1993 to prepare astronauts for station assembly and maintenance. These will help to predict the length of specific tasks and investigate the use of handrails and foot restraints while manoeuvring equipment similar to that being designed for Freedom.

Columbia (STS-55)

The first Spacelab module flight of 1993 is a German-sponsored mission of 9 days duration to continue studies in materials and life sciences research to further technology development for use in the space station era. (See opposite).

Discovery (STS-56)

Included on this flight is ODERACS or Orbital Debris and Radar Calibration Spheres. This experiment will help calibrate ground-based instruments used to track orbital debris. Three pairs of precisely-machined metal spheres of different diameters will be released from a canister in the payload bay and will be tracked by ground radar to calibrate them more accurately. This will allow a better determination of the life expectancy of space debris, assisting in the development of Freedom's protective shield. ODERACS was flown on STS-53 in December 1992, but a loss of battery power inside the canister prevented release of the spheres. (See p. 86).

Endeavour (STS-57)

An experiment, which first flew on the STS-54 mission in January, will be flown as a full experiment on this mission to grow larger, high fidelity tissue cells for clinical research. STS-57 will carry cancer cells to be grown in the chamber and brought back for study. On the ground, cells tend to lose their neutral buoyancy or ability to remain suspended in the nutritional fluids inside the chamber. In space, however, the cells can grow larger without floating toward the chamber walls. On the Shuttle, the experiment will serve as the "foundation experiment" for the development of bioreactor technology on the space station. Growing cells to full maturity may take several months, which only can be done on long-duration flights aboard the station.

Spacehab, which has its first flight, will carry a space station flight experiment called the Environmental Control and Life Support Systems Flight Experiment, containing two critical components of Freedom's environmental control system. This mission is being considered for another spacewalk to continue proficiency training for space station assembly and maintenance.

Discovery (STS-51)

The crew of STS-51 will expose various materials to the space environment to determine which are best for use in future spacecraft design, including the space station, to ensure long-term survivability in space. Freedom is designed for a minimum 30-year life.

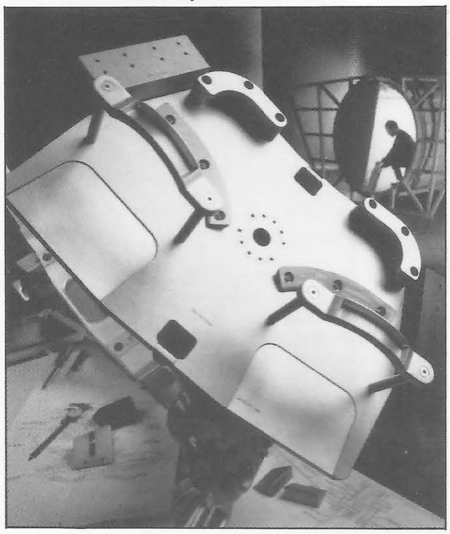
This flight is being considered for another spacewalk to continue proficiency training for space station assembly and maintenance. Current plans call for EVAs to occur on either this mission or on STS-57 in April, or both.

Columbia (STS-58)

This Life Sciences mission (SLS-2) is the second devoted exclusively to understanding how the human body reacts and adapts itself to the space flight environment and is of particular interest since plans call for astronauts to live aboard Freedom for periods of 90 days or more. It will continue the medical evaluations of SLS-1 which flew for 9 days in June 1991.

This will be the second "extended duration" Shuttle mission. STS-50 in June 1992 lasted 14 days and is the longest shuttle mission to date. SLS-2 will continue the process of certifying the Shuttle to conduct longer duration flights docked to Freedom.

A Foothold in Space



Lockheed, the principal subcontractor on the Space Station Freedom program, has developed an articulating portable foot restraint to aid astronauts while working outside Space Station Freedom. Lockheed Engineering & Sciences Company (LESC) designed the device for NASA to be attached at various points along the orbiting structure to aid astronauts who will assemble and maintain Space Station Freedom during extravehicular activity. The restraint can also be used with a portable work platform.
Eric Schulzinger/Lockheed

Discovery (STS-60)

This second Spacehab flight will carry a large complement of secondary experiments in the additional middeck locker space. The module is attached to the orbiter's airlock and more than doubles the space to conduct secondary materials and life sciences investigations as precursor experiments to those that will fly on Freedom.

A Russian cosmonaut will be among the crew member aboard Discovery for STS-60 (see *Spaceflight*, December 1992, p.382). A series of medical evaluations will further investigate the adaptation of the human body to space flight as well as readaptation to the Earth environment.

Endeavour (STS-61)

The final mission of 1993 highlights the first servicing mission to the Hubble Space Telescope (HST). The work scheduled, as well as spacewalks involved will provide further data for the space station era.

Long-Stay Mir Missions to Continue in 1993

The Russian manned flight programme of 1993 got underway with the launch of cosmonauts Gennady Manakov and Alexander Poleshchuk in Soyuz TM-16 and its docking with the Mir space station in late January. The docking procedure provided a test for a manned docking system that may be used in a joint mission with the US planned for 1995.

The future of the Russian space programme is however in doubt due to funding problems, but it is hoped to keep Mir in orbit beyond its originally intended lifespan until at least 1996. Manakov and Poleshchuk are expected to return to Earth in the Soyuz TM-16 landing capsule on about 14 July.

Cosmonauts Anatoly Solovyov and Sergei Avdeyev, who had been aboard Mir since 29 July 1992, returned safely to Earth on 1 February in the Soyuz TM-15 landing capsule touching down on the steppes of Kazakhstan.

The next manned flight to Mir will be the fourth Russian-French flight with Frenchman Jean-Pierre Haignere (back-up Claudie Andre-Deshaye) spending 20 days at Mir before returning to Earth in the Soyuz TM-17 landing capsule. This mission was originally planned for 1994 but was brought forward to 1 July 1993 in the absence of other contenders for cosmonaut-research flights. The accompanying cosmonauts, who are expected to be Tsibliyev and Kaleri, will return to Earth in January 1994.

For the end of 1993 a main Mir mission is planned with a physician to spend a year and a half in space.

India Set to Launch New Space Vehicle

A four-stage Indian rocket, the Polar Satellite Launch Vehicle, will place a one-ton remote-sensing satellite in orbit on its first launch in March from Sriharikota, India's main launch pad, which is close to the city of Madras.

The PSLV, which incorporates advanced liquid propulsion technology, is a successor to the Augmented Satellite Launch Vehicle, successfully launched in May 1992 after several abortive efforts. The PSLV is one of two powerful rockets that India is developing. The other is the Geostationary Launch Vehicle, whose planned development by 1996 will give India an undisputed intercontinental ballistic missile capability. According to the Indian government, the development of the PSLV and GSLV will make India self-reliant in space technology and enable it to compete in the multibillion-dollar international space market. India has the most advanced space programme in the Third World. In 1980, it surprised the international community by placing a satellite in orbit.

ESA Launch Diary for 1993

Ariane Programme and Space Shuttle Involvement

March

STS-55/Spacelab D2: Second German Spacelab mission with heavy ESA involvement. Launch delayed until early March.

STS-56/Atlas 2: Follow-up of Atlas-1 mission for atmospheric applications and science. Launch scheduled for late March but may be delayed.

April

Ariane V57: Launch of Astra 1C telecommunications satellite with Arsene as secondary passenger.

STS-57/Eureca: Retrieval mission of ESA's Eureca platform.

May

Ariane V58: Launch of Hispasat 1B and Insat 2B telecommunications satellites.

June

Ariane 5 M1: First firing test of solid rocket booster with flight structure in Kourou.

September

Ariane V59: Launch of Spot 3 and Stella for France.

October

Ariane V60: Launch of Intelsat VII-F1 telecommunications satellite.

Ariane 5 M2: Second firing test of the Ariane 5 solid rocket booster with flight structure in Kourou.

November

Ariane V61/MOP-3: Launch of ESA's meteorological satellite Meteosat MOP-3 and the Mexican telecommunications satellite Solidaridad 1.

Maser 6 and Texus 31 sounding rocket launch with major ESA payload participation.

December

STS-61/HST servicing: Repair mission of Hubble Space Telescope with ESA astronaut Claude Nicollier on his second shuttle flight.

Ariane V62: launch of DirecTV1 and Thaicom telecommunications satellites.

Dates of launches are very dependent on many factors such as readiness of spacecraft and/ or launcher system and may remain unknown for quite some time.

STS-55

ESA's Spacelab in Launch Delay

Europe and ESA look forward to being once more in the forefront of manned space flight with the launch of the second German Spacelab mission (D-2). The original February launch has, however, been put off until at least the second week of March to allow inspection of all 22 pumps of Columbia's engines following a mix-up involving the use of old instead of new metal clips to hold the pumps' seals in place.

Columbia carries in its cargo bay the ESA developed Spacelab on a 9-day mission to conduct fundamental research. A crew of seven astronauts, five from NASA and two payload specialists from DLR - the German Aerospace Research Establishment - have the task of carrying out some 90 experiments, 32 of which have been funded and developed under ESA responsibility for scientists from university and research institutes spread all over Europe.

Spacelab, as a manned orbiting laboratory, has already flown six times. The year 1993 marks the 10th anniversary of the first flight in November 1983 (STS-9/ Spacelab 1).

As was the case for the Spacelab D-1 mission in 1985, DLR has been entrusted by the German Federal Ministry for Research and Technology (BMFT) with the project management, the training of the scientific astronauts and the operation of the payload. DLR's dedicated space operations control centre for D-2 is located in Oberpfaffenhofen, near Munich.

Pegasus Launch

At 9:32 am EDT on 9 February, a Pegasus rocket launched from a B-52 aircraft at 43,000 feet altitude and some 80 miles off Florida's east coast carried a Brazilian environmental sciences satellite into Earth orbit.

From an altitude of about 550 miles, the satellite, built and owned by Brazil, is to be used to collect environmental data from ground sensors in the Amazon River Basin and surrounding rain forests and replace the need for arduous ground trips into remote regions.

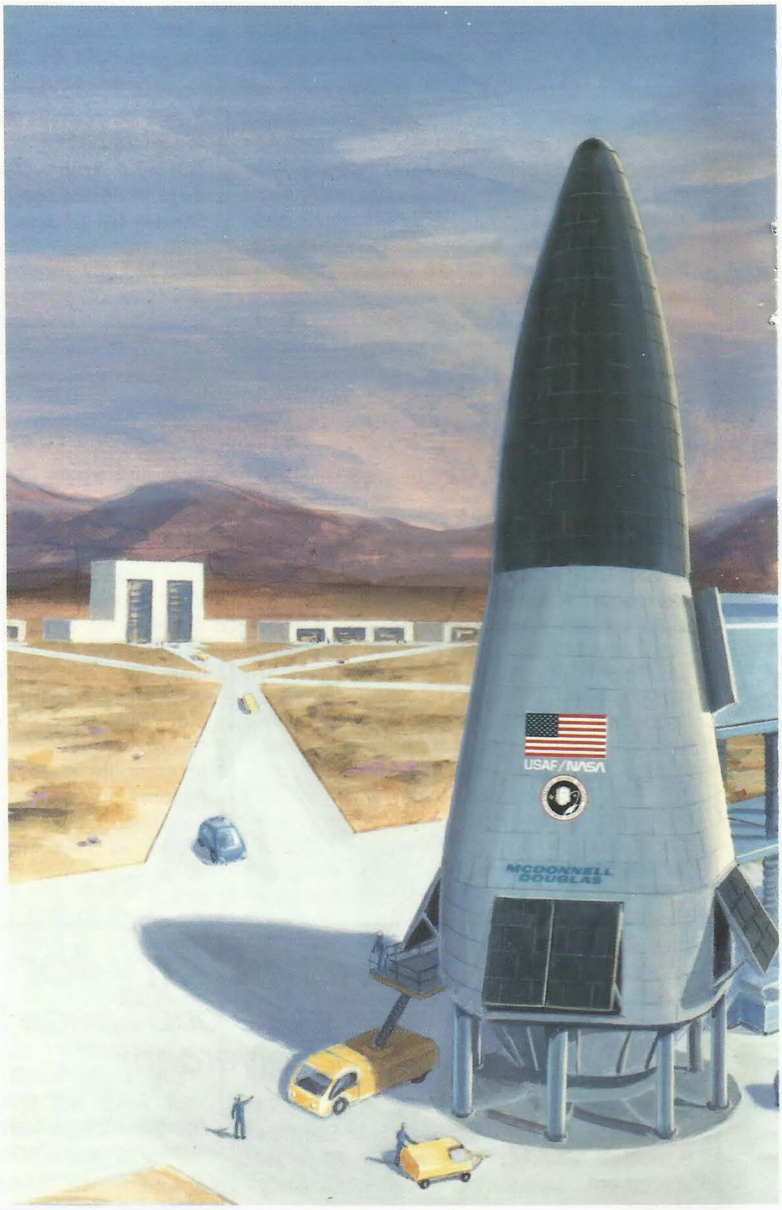
Delta Launch

A Delta II rocket blasted off at 9:55 pm on 2 February from Cape Canaveral Air Force Station to launch the 18th of a series of navigation satellites. The $65 million Navstar Global Positioning System satellite is capable of locating receiver-equipped military personnel within 50 feet and measuring their speed to within a fraction of a mile per hour and giving time to within a microsecond. US military forces relied heavily on Navstar satellite during the Gulf War. Civilians using the satellites can determine their positions within 325 feet. The Air Force eventually wants 24 Navstars in orbit 12,500 miles high.

The First Reusable SSTO S

For the Exploitation of Space and Expansion of Humankin

In August 1991, the Strategic Defense Initiative Office (SDIO) awarded a $58.9 million, Phase II SSTO Technology Demonstration contract to the McDonnell Douglas Space Systems Company (MDSSC). The contract calls for MDSSC to design an Single-Stage-to-Orbit (SSTO), totally reusable spacecraft that can carry SDIO's relatively large numbers of small payloads (under 20,000 lbs). Current launch vehicles cost over $10,000 per pound-to-orbit; SDIO's goal is to cut that to less than $1,000 per pound. The award follows a competitive Phase I definition and risk-reduction study, begun in December 1990 by MDSSC, General Dynamics, Boeing and Rockwell.



Artist's impression of the Delta Clipper Single-Stage-to-Orbit spacecraft on the laun

Background

MDSSC's winning answer is the Delta Clipper, a vertical take-off and landing (VTOL) design. For the Phase II contract, MDSSC will construct a 1/3 scale flying prototype, the DC-X, that, although not capable of orbit, will demonstrate the design's launch, manoeuvring, hovering and landing capabilities. If Phase II is successful, then during Phase III of the SSTO project, to last from 1993 through 1996, MDSSC will design, construct and test the DC-Y, a full-scale, orbit-capable prototype. Finally, during Phase IV, MDSSC will design - for first launch sometime during 1999 - the production version of the Delta Clipper (designated, not accidentally, the DC-1).

It should be noted that, for the time being, Phases III and IV are contingent upon additional funding from sources outside the SDIO, such as NASA or the Air Force, or even private investment. Unfortunately, SDIO's budget is not capable of funding the DC-Y or the DC-1 unaided.

To provide the wide range of expertise necessary, MDSSC has formed a wide-ranging team of aerospace companies. MDSSC (itself a subsidiary of McDonnell Douglas) is performing systems engineering and project management, Aerojet GenCorp and Pratt & Whitney are developing the engines; Messerschmitt-Blkow-Blohm is designing the landing gear and providing general reusable systems and VTOL experience; Martin Marietta is providing experience in cryogenic ground operations and NASP-derived technology; two other McDonnell Douglas subsidiaries, Douglas Aircraft Corporation and McDonnell Aircraft (MCAIR), are providing commercial and high-performance military aircraft technology; and a large group of other subcontractors are bringing expertise in various space systems.

Technical Characteristics

The full scale Delta Clipper will stand 127 feet high and be 30 feet wide at base, weigh approximately 80,000 pounds empty, carry 20,000 pounds of cargo and burn 940,000 pounds of liquid hydrogen and oxygen through a ring of engines in its base. The 1/3 scale DC-X will use four modified Pratt & Whitney RL-10A-4 bell-nozzle engines. MDSSC has not decided upon the exact configuration for the DC-Y yet; either multiple bell-nozzled engines (10 or 12) or a variation on the Rocketdyne-developed "aerospike" engine may be used.

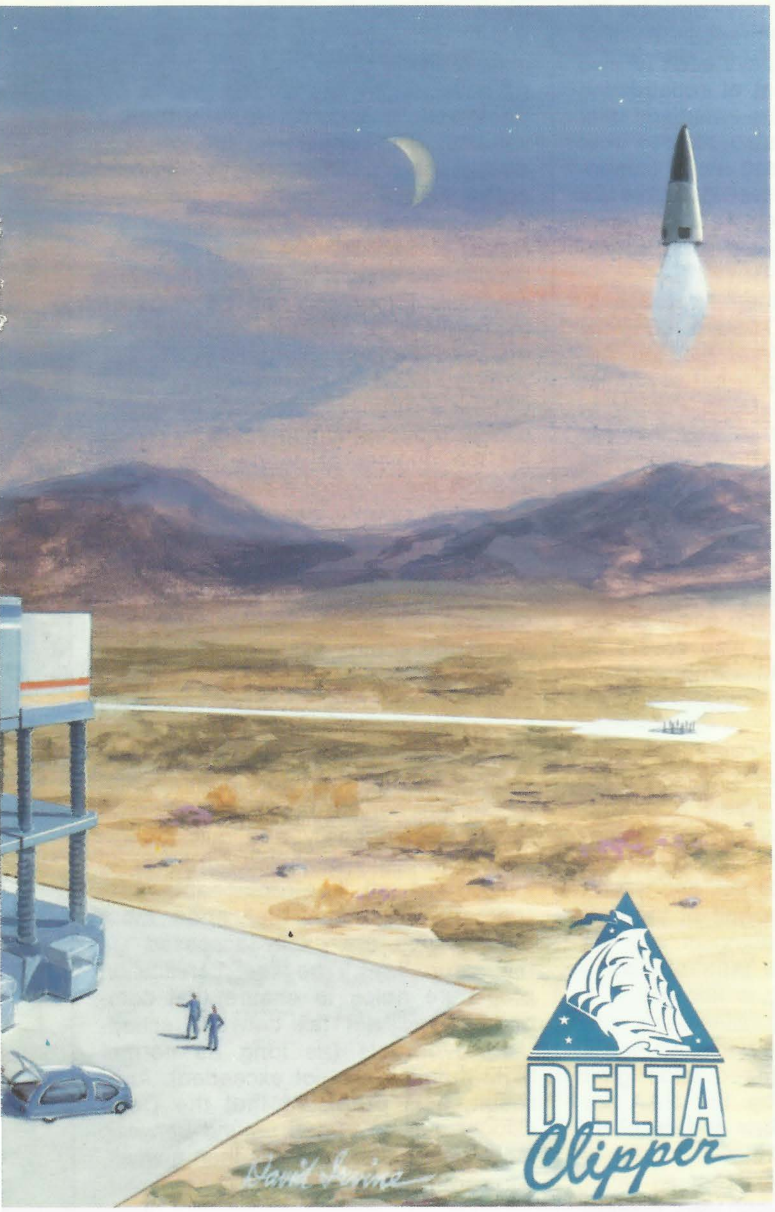
Unlike conventional rocket engines, which have bell-shaped nozzles in which the gases from the combustion chamber expand, the aerospike engine features a toroidal combustion chamber, with a ring of exhaust ports running around the base of the spacecraft. The chambers' exhaust gases expand against a large central cone, or plug, which is made of high-temperature materials and regeneratively cooled by the cryogenic fuel. In general, the nozzle of a rocket engine must be optimised for a particular altitude of operation. Initial design work on the aerospike engine indicated that, unlike fixed-bell nozzle rocket engines, it would automatically adjust itself for altitude. In addition, since an aerospike engine makes up the entire base of the vehicle, the plug can double as a heat shield for reentry. However, the Clipper does not require this capability and recent studies indicate that the aerospike may not be as efficient at higher altitudes as originally thought. Both the aerospike engine and conventional bell-nozzled engines are being integrated for the DC-Y and the DC-1.

In a dramatic departure from earlier SSTO designs, which reentered the atmosphere tail-first in a manner similar to an Apollo capsule, the Delta Clipper reenters nose-first at a high angle of attack. Its shape is, in fact, a supersonic lifting body/flying wing capable of 1,600 miles of cross-range manoeuvring during reentry. Four extendable control surfaces around the base, together with manoeuvring thrusters, provide control in the atmosphere. Once the craft has reached approximately 20,000 feet and 180 knots, the

pacecraft

d into the Solar System

BY W. PAUL BLASE
Virginia, USA



ch pad. McDonnell Douglas

engines ignite and idle and the nose is pulled up so that the craft is vertical with its base downward. The engines are then throttled up and the craft hovers, descends, extends the landing gear and lands. A landing pad less than 300 feet in diameter is all that is required.

Although the National Aerospace Plane program (NASP), will not construct the hypersonic X-30 for several years yet, the Delta Clipper may truly be called the first NASP derivative. It draws heavily upon NASP for advanced composite materials for its structure and fuel tanks, new thermal shielding materials and thermal and aerodynamic computer simulation software. The structural truss of the Clipper is graphite/epoxy; the skin is graphite/epoxy and aluminium in a honeycomb sandwich; and carbon-carbon and carbon-silicon carbide insulation shield the Clipper from the heat of reentry. The landing gear is made from titanium-silicon carbide composite; the liquid hydrogen (LH) tank is graphite/epoxy and the liquid oxygen (LOX) tank is made from a new aluminium-copper-lithium alloy.

All current rocket launchers are derived from 1960s era ICBM designs, and man-rating procedures are merely ways of producing man-rated ammunition. Rocket designers are conservative by nature and the high cost of both the vehicles and their payloads causes them to refine the same basic concepts continuously to finer and finer degrees, taking few risks with radically new ways of doing things. This has resulted in a situation very much like trying to pull a semi-trailer with a racecar. Like a racecar, ICBM-based rockets are designed to get maximum performance from minimum equipment. Technology is pushed to the very brink to wring out that last ounce of thrust. However, it is an engineering truism that when one gets near the theoretical limits of a system, every additional 10 percent increase in performance doubles the systems cost and halves its reliability.

This high-performance design philosophy has several side effects that, in turn, drive launch costs even higher. First, the premium placed on vehicle mass means that there is no room for redundant control systems. There is no spare engine thrust and there is little capacity for rugged, resilient construction. Adding in the fact that the vehicle is meant to be a one-shot, disposable system, with no capability to safely recover from an aborted launch, the following hold true:

- launches are generally delayed (at substantial cost) if there is any hint of a possible problem with the vehicle;
- launches are delayed if there is any possibility of bad weather;
- any failure in a rocket during a flight almost certainly results in the vehicle's (and cargo's) destruction, either through the failure itself or by range-control when the rocket threatens to leave the flight path.

Not only do these factors drive up cost directly but the high risk means that launch-insurance premiums are astronomical.

Secondly, the complexity of current launch vehicles and their heavy requirement for service means that many personnel are required to launch and maintain them. The Space Shuttle, for instance, requires over 40,000 people to maintain it, support its operation, and turn it around between missions. To paraphrase an individual interviewed for this article: adding hardware to a project increases its cost linearly; adding people increases costs exponentially. The greater the number of people involved, the greater the infrastructure that must be devoted to supporting *them*, the greater the chances for errors, and the larger (and slower) the bureaucracy required.

Since the *raison d'etre* for the entire SSTO effort is low launch costs, the Delta Clipper is designed from the start to be a true, long distance cargo haulier. In fact, the Clipper is intended to operate in the same manner as a modern commercial aircraft. Like an airliner, its design is centred on flexibility, a long service life and the troika of safety, reliability and ruggedness.

Delta Clipper is capable of carrying either passengers or cargo. In an interesting twist, the Delta Clipper's cargo is carried not in the nose of the craft (a traditional location), but in two bays in the centre, with LH and LOX tanks above and below. Each bay contains a mission module that may, in turn, contain either crew or cargo. The Clipper may fly unmanned with two cargo modules, say for a routine satellite launch or space station resupply mission. If a manned mission is required, one module would contain a crew/control cabin; the other may then contain either cargo, a pressurised working module, or a remote manipulator arm similar to the one used in the Shuttle. Externally, the modules are identical, having standardised connections to the

Clipper for power, cooling and the control interface. A customer can take as long as it likes to fit a cargo into a module and then launch it on the next available Clipper.

Adding to this flexibility is the fact that since the Clipper does not drop stages after launch and because of its inherent reliability, it need not be launched only from coastal sites. Since the craft ascends vertically for the first part of the launch, like any rocket, noise pollution is kept to a minimum and the launch sites could be incorporated into existing airports. It also, incidentally, means that no carrier vehicle is necessary to move a Clipper from one launch site to another: the craft merely does a suborbital hop.

Reusability and a long service life are, of course, a major feature. It is important to note, however, that this extends beyond the basic structure of the craft to all the components and subsystems. The Space Shuttle is reusable but its engines and many other onboard systems must be serviced or replaced between launches. In contrast, MDSSC is specifying a 20 year lifetime for the structure of the Clipper and a minimum of 200 launches between major overhauls on the engines, figures comparable to a modern jet airliner. All of the electrical and hydraulic systems are also designed for long, maintenance-free service.

"Airliner" Approach

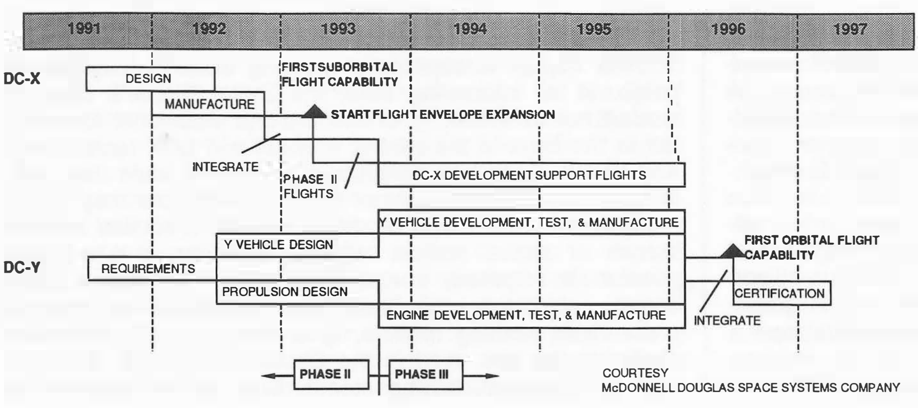
Long component service lives are made possible by the Clipper's 4:1 dry-weight to payload ratio, almost 2.5 times that of the Space Shuttle. Lowering the spacecraft's mass to such a low level, for a given payload size, enables the designers to use simpler and more reliable, *albeit* heavier, engines and other essential components. It also enables them to use more engines in the base of the craft. This last means that each engine may be run at a greatly reduced power level during flight. The normal operating level for the Clipper's engines is to be 90% of rated power; the engines would go to 100% of full rated power during an emergency abort situation (two engines out), could safely be driven to 110% for limited periods and redline (damage to the engine is probable) at 115%. In contrast, the Space Shuttle's main engines, which must be completely overhauled and tested between flights, routinely operate at 105% of rated performance.

A long service life pays back for two reasons. First the cost of constructing a launch vehicle can be amortised over many launches. It also means that every Delta Clipper, and every component, may be flight tested before its first cargo-carrying launch. It is never necessary to fly a critical mission with unproven hardware.

As part of its "airliner" approach to space operations, MDSSC is currently working with the Federal Aviation Administration to develop a set of criteria for fleet-certifying the Delta Clipper in almost exactly the same way that airliners are certified. This certification requires a vehicle designed to operate within a specific set of margins with respect to thermal and mechanical loads, and to incorporate aerodynamic controls capable of handling the entire span of normal and some abnormal flight conditions. It also covers all the craft's maintenance and support infrastructure, both equipment and procedures.

Like an airliner, the Clipper is being designed so that it can either continue with flight or safely abort and land under a wide variety of conditions. During takeoff, it will be able to achieve orbit if any two engines fail, and will be able to safely land on half of them. It will be capable of landing in any flat area after hovering to burn off fuel if an emergency landing is necessary. It is being designed for all-weather capability and will be able to land under the 43 knot sharp-edged wind gust conditions required by the FAA for commercial aircraft. The end result is maximum confidence that the craft is both safe and reliable under all rated conditions. Not only can the Clipper operate under conditions that shut down current launch vehicles (e.g. the frequent delays in Space Shuttle launches due to inclement weather at the emergency landing sites), but it will yield significant reductions in insurance premiums, both for the carrier and for the customers.

Schedule for the development of the Delta Clipper. *McDonnell Douglas*



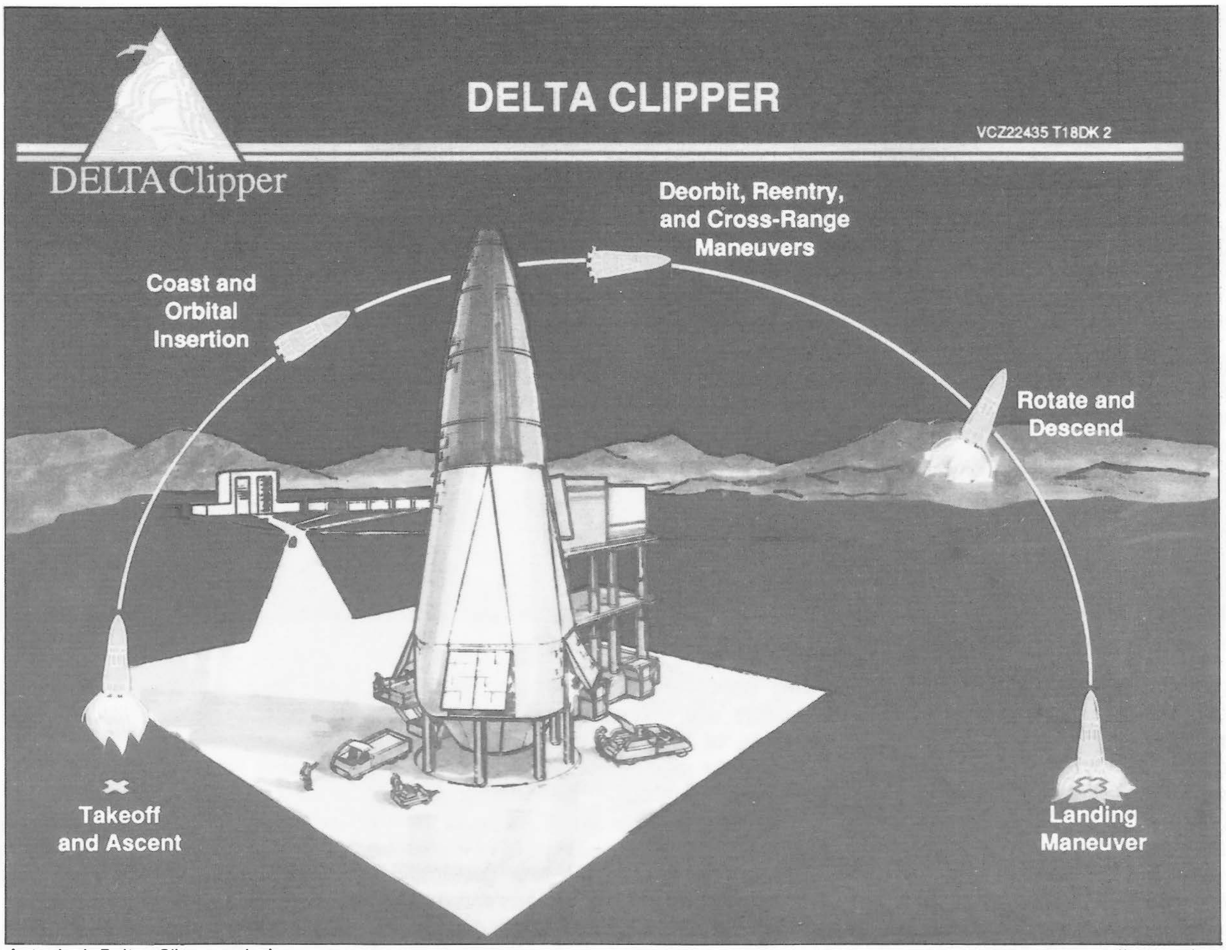
The airline-style operating approach also extends to the launch support facilities. The Delta Clipper does not require a complex launch facility or gantry. The launch pad consists of flame ducts and support pylons (to save weight, the landing gear is not designed to support a fully-fuelled vehicle). The cryogenic fuel-handling equipment is built into the pad and the entire refuelling operation made as automatic as possible. No special vehicles or facilities will be required to service the Clipper or to load the cargo modules. Everything can be done on the pad with ordinary scissor-jack trucks of the kind now used in airports.

Even more importantly, the Delta Clipper's airliner approach to rocket design reduces launch costs by reducing the number of people required to support the system. It will require less than 600 people per craft, including administrative personnel - a number comparable with that required by commercial aircraft. The rugged, redundant design of the structure, engines and control systems means that very little servicing will be required between launches. Most servicing will be accomplished during routine maintenance operations. In addition, the Clipper is designed for maintainability, so that service that is required can be performed easily and quickly. Engines can easily be pulled out for servicing, and all line-replaceable-units (primarily avionics) that need most maintenance are easily accessed *via* the cargo bays. The fleet certification procedure helps to ensure that components will not fail between scheduled overhauls (as long as normal flight margins are not exceeded). As a result, it is predicted that the Delta Clipper can be turned around between landing and launch in less than a week, possibly even within a day.

From a Long History of Ideas

The craft is the end result of over thirty years of designs and dreams. Its roots began in the late 1950s with the Douglas Aircraft Reusable Interplanetary Transport Approach (RITA), a nuclear SSTO rocket which used engines similar to the recently announced Timberwind nuclear rocket. RITA was based, in turn, on work done by Douglas Aircraft for a nuclear-powered bomber for the US Air Force earlier in the decade. Chief design engineer for the Douglas Missiles and Space Department and in charge of the RITA work, was Maxwell Hunter.

In 1969, Douglas Aircraft aerospace engineer Philip Bono proposed a series of SSTO designs [1], based upon the Rocketdyne "aerospike" engine design. Bono had joined



A typical Delta Clipper mission sequence. *McDonnell Douglas*

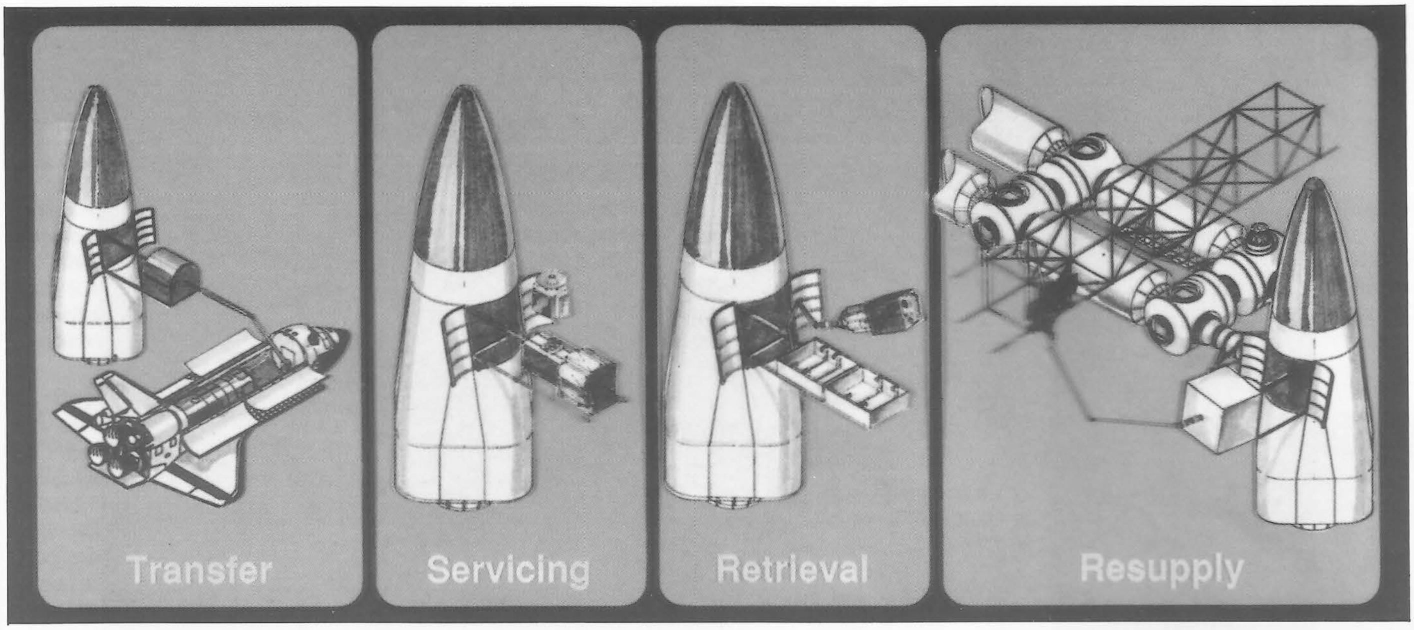
Hunter's organisation in 1960 - too late for the RITA work, but just in time to become Involved in a Douglas rocket effort started as a response to Sputnik. Utilising the earlier RITA work; NASA and the US Air Force work on lifting bodies, particularly the Boeing Dyna-Soar (never built) and the X-24A; and basic Saturn rocket technology, Bono's designs progressed from the Saturn Application Single - Stage - To - Orbit (SASSTO), which consisted of a Gemini crew capsule on top of a 45 foot fuel/aerospike engine module, to the *Ithacus,* a monstrous 200 foot tall intercontinental passenger/cargo carrier that could haul 1,200 passengers 7,500 miles in slightly over 1/2 hour. Of greatest interest, and bearing the greatest resemblance to the Delta Clipper, is the *Hyperion* - a bullet shaped SSTO capable of carrying 8,100 pounds into low-Earth orbit. This design carried the cargo in a nose fairing on top of the fuel tanks and, using the capability of the aerospike engine to serve as a heat shield, reentered the atmosphere tall-first and then hovered to a vertical landing.

Although Bono's ideas never came to direct fruition, they were picked up by a private aerospace consulting engineer, Gary Hudson - founder of Pacific American Launch Systems, Inc., an aerospace consulting company. In 1972 Hudson proposed the *Phoenix,* a 53 foot Hyperion-style SSTO capable of hauling 5 tons into LEO. Up until 1991, Mr Hudson attempted, with some success, to obtain private venture capital to construct and operate Phoenix as a private launch service, totally Independent of government financing and run In the same manner as an airline. Unfortunately, several occurrences in the space industry, including the destruction of the Space Shuttle Challenger and the DARPA (Defense Advanced Research Projects Agency) decision to contract with another launch company, Orbital Science, caused his backers to pull out. During the SDIO SSTO effort, Mr Hudson consulted with Rockwell and Boeing In their Phase I proposals.

In 1965, Maxwell Hunter left the National Space Council staff, which he had joined after leaving Douglas in 1961, for Lockheed. Immediately after his arrival he began work on the *Starclipper,* a direct SSTO descendant of RITA. One of the most important results of this work was his application of ATA (Air Transport Association) cost-effectiveness formulae to the operation of RITA and *Starclipper.* These formulae, an aeronautics industry standard set, are usually used to estimate the operating costs of proposed transport aircraft for civilian use. The results showed that it was possible to build a launch system that could operate for costs comparable to those of commercial aviation; results that would subsequently be crucial to Hudson's *Phoenix* and the Delta Clipper.

Among other accomplishments during his stay at Lockheed, Hunter directed both the programme that developed the thermal protection tiles for the Space Shuttle and the early phases of the Hubble Space Telescope. It is Interesting to note that the highly successful Shuttle tile material was originally proposed and developed for the *Starclipper* effort, to replace the one-time-use ablative insulation used for the Mercury, Gemini and Apollo capsules.

During the early 1980s Hunter directed Lockheed's 'X-Rocket' study. Based upon Gary Hudson's *Phoenix,* the 'X' was a 60 ft high Hyperion/Phoenix style SSTO that featured the basic blunt cone shape and reentry/hover-to-landing mission profile of its predecessors. It Is a direct ancestor of the DC-X, featuring a nose-first atmospheric reentry and multiple bell-nozzled engines In a plug-cluster configuration, similar to the aerospike, but with discrete engines arranged in a ring, instead of a continuous toroidal combustion chamber. Most importantly, It featured the *Phoenix* concept of a drastic reduction in the "standing army" (Hunter's term): the number of people necessary to maintain and support the craft between launches.



Typical on-orbit activities of the Delta Clipper craft. *McDonnell Douglas*

Although Lockheed cancelled the 'X-Rocket' program, Hunter - after retiring in 1985 - kept the idea alive. He renamed it the "SSX" (Space Ship eXperimental), and promoted the concept both in collaboration with Gary Hudson and by himself. In 1988, Hudson and Hunter briefed and sold the Phoenix/SSX SSTO concept to the Citizen's Advisory Council on National Space Policy and to US Army General (retired) Daniel O. Graham of High Frontier, an organisation that promotes the large scale development of space - Including the Strategic Defense Initiative.

In 1989, Hunter and High Frontier Presented the Phoenix/SSX SSTO concept to the National Space Council, chaired by Vice President Dan Quayle. Then , the Air Force (through The Aerospace Corporation, a California based consulting firm) reviewed the concept, releasing a generally favourable report in July 1989. The SDIO SSTO Phase I study contracts followed a year and a half later.

Looking to the Future

Like its predecessors, the Douglas Aircraft Corp. DC-2 and DC-3 of the 1940s, the Delta Clipper promises to transform an industry. By taking advantage of the latest technology, yet insisting that this technology be proven and by insisting that the reduction of operational costs be a major design criteria, McDonnell Douglas stands a good chance of accomplishing its goal of creating a spacecraft that can be operated as efficiently as a commercial airliner.

Current launch systems are expensive and, by the standards of every other transportation industry, unreliable. In a classic Catch-22 lock, no truly new rocket designs have been tried (including the Shuttle) because the launch market is so small, while many potential customers and private investors are scared away from space because of the high costs involved in getting into orbit. Launch facilities are built and operated by national governments, for national agendas, and the support services necessary for launching a spacecraft are generally provided either by a government agency or by a government contractor. There is no independent, non-government infrastructure, such as the abundance of private industries that support commercial aviation.

The Delta Clipper promises to bring the cost of access to space down to the point where private enterprise can own and operate spacecraft. The reusability and long design life will allow an operator to amortise the cost of the craft over many launches, reducing the cost per launch.

Additional savings may be realised through its low required maintenance, non-complex ground facilities and the lower number of people required for operation. Finally, the craft's reliability and safety should greatly lower the cost of launch insurance - a major contributor to launch costs. Together, all these factors should work together to drive down launch cost to the point where a truly commercial launch Industry, along the lines of the modern airline industry, Is feasible.

As for any new Industry, once the cost reaches a certain point new uses for it will be found and the whole process will begin to snowball. Once launch costs drop to the point where industry can afford to experiment with Null-G and high-vacuum processes on a routine basis, space stations can be built along the lines of modern industrial laboratories, either by the Industries themselves, or by separate service companies serving many customers. Once space stations become economically feasible for industrial purposes, satellite builders can construct their 'birds' for in-orbit assembly and repair - thus drastically reducing *their* costs.

This last step would trigger a need for in-orbit 'tugs' and other vehicles designed purely for in-space use. We now reach the point where service and supply companies spring up to service the requirements of the space industry and the historical demand/cost snowball cycle begins. The current high cost of the technologies required for space travel (such as advanced composites and radiation-resistant electronics) is due, in large part, to the limited markets for them. A larger market for a technology means that mass-production techniques can be applied and that specialty companies can be formed to produce them, typically at very high efficiencies. The reduced cost then increases the number of potential uses for the technology, making an even larger market and inspiring even more methods and techniques for manufacturing the technology and meeting demand - and even more applications.

As a result of this whole process, the cost of space travel should drop, within twenty or thirty years, to the point where such developments as lunar colonies and Solar Power Satellites become economically feasible. Just as trading between continents was made possible by the development of the large cargo vessel, and modern urban society was made possible by the automobile and telephone, so the Delta Clipper should, ultimately, make possible the exploitation of space and the expansion of humankind into the Solar System.

Reference

1. Bono, Philip and Gatland, Kenneth, "Frontiers of Space", Macmillan Publishing Co., Inc., New York; 1976.

Society News

Developments in X-Ray Astronomy

The meeting at the Society's HQ on 6 January featured a most interesting talk by Professor Ken Pounds of Leicester University describing the "Development of X-ray Astronomy in the UK".

Professor Pounds recalled that X-ray astronomy began just over 30 years ago when a small detector was launched by a sounding rocket from White Sands Proving Ground. Its (unsuccessful) objective was to study X-ray emission from the surface of the Moon, not accomplished until 29 June 1990 when the historic ROSAT picture was taken of the Moon in X-rays.

X-ray astronomy has proved to be a highly productive area of study. The last 20 years has seen an escalating number of discoveries, a tendency which will probably continue until the turn of the century.

Three areas of fundamental importance which are currently dominating astronomical research are:-

1. The Early Universe, Dark Matter and the Origin of Galaxies.
2. The Physics of Stellar Collapse e.g. the collapse of stars, novae and black holes.
3. The formation of stars and planets and the origin of life.

The first two are being addressed by observations in the X-ray band. ROSAT, visible as a naked-eye object of magnitude 3 or 4 which goes over the UK 3 or 4 times daily, was used to illustrate the problems in the design of X-ray telescopes, while Tycho Brahe's nova of 1572 and Abell 2256 were used to illustrate some of the scientific results achieved. It was pointed out that the number of satellites orbiting or projected, which are concerned with the study of the Universe in the optical, ultraviolet, millimetre and infrared wavelengths, is quite substantial. There is COBE (mm), Hipparcos (optical), IUE (UV), Hubble (optical) and Rosat (X-ray). The status of those currently listed by ESA alone for the next decade illustrates the point also, *viz* the Infrared Space Observatory (ISO), the Solar-Terrestrial Science projects (Soho and Cluster), Cassini/Huygens and XMM. Additional examples are Astro D, a Japanese X-ray mission scheduled for 1993, and SIRT-F, the US infra-red 'Great Observatory' scheduled for the turn of the century.

Themes for 1993-1994 issues of JBIS

A major ***JBIS*** Innovative publishing project is underway which will feature many new aspects of space flight throughout 1993-1994, the Society's 60th Anniversary year.

Details of those now listed for 1993 are as follows:-

Jan	New Space Concepts (Pt IV)
Feb	Science Systems in Space
Mar	General Issue on Space Medicine and Space Astronomy
Apr	Advances in Space Technology
May	Pioneering Rocketry & Spaceflight (Pt II)
Jun	Marcol in Space (Pt II)
Jul	Terraforming
Aug	Space Science: Developments in X-Ray Astronomy
Sep	Report on the Extreme Ultraviolet Explorer Misson
Oct	The Impact of Space on Social Culture
Nov	Nanotechnology (Pt II)
Dec	Turin Conference on Space Missions and Astrodynamics

The list embraces the past history of space flight, some of its most important current projects, future developments in space propulsion, nanotechnology and the impact of these topics on human culture.

1994 will see the appearance of Part III of Exobiology, an outstanding series of fundamental studies which examine the biological development of life together with two educational issues, *viz* - Support of the University Community for Space Science and Technology and Space Educaton in the 90s and Beyond. Two Journals will examine further the incredible developments in computer technology applied to space flight, in which the UK plays a leading role, while several other issues will expand our knowledge base on space history.

* * *

OBITUARY *Patrick Girton*

We are extremely sorry to record the death of Patrick Girton, a long-standing and active member of the Library Working Group. During the war years Pat was in Air Sea Rescue, a part of Coastal Command. Pilots would call on him after they had returned to base to say "Thanks for getting us back home". Pat joined the Society as a Member in January 1959, subsequently transferring to the former grade of Associate Fellow in 1975 and to full Fellowship some years later.

Besides his other activities for the Society, Pat's expertise as a technical company representative was always freely available to the Society. He was always cheerful and supportive of the Society's work and will be sadly missed by all his colleagues.

Endeavour's Third Mission

STS-54
Astrophysics
X-Ray Experiments

The STS-54 flight crew enjoys breakfast in the Operations and Checkout Building prior to suiting up and heading to Launch Pad 39B. From left are Mission Specialist Gregory J. Harbaugh; Pilot Donald R. McMonagle; Mission Commander John H. Casper; and Mission Specialists Mario Runco Jr. and Susan J. Helms. *NASA*

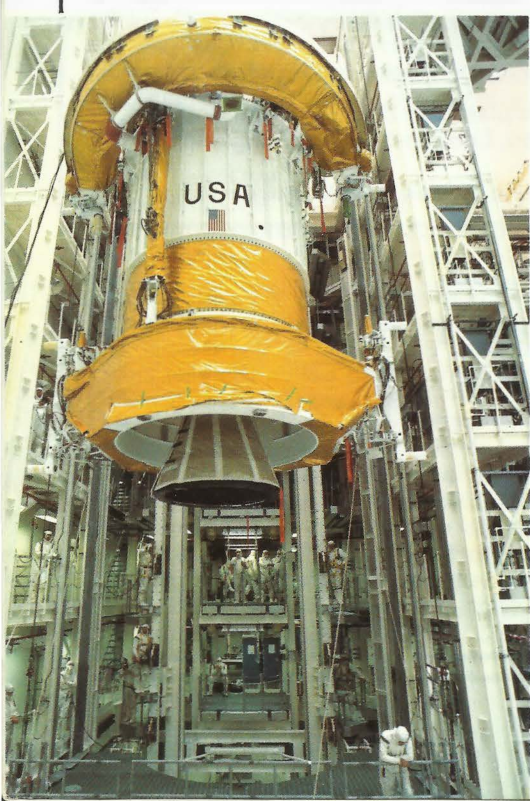
First Training EVA for Space Station Assembly

The Space Shuttle Endeavour was launched on Shuttle Mission STS-54 from the Kennedy Space Center's Launch Complex 39B at 8:59 am on Wednesday January 13, 1993. This was the third mission for the Endeavour orbiter and it was KSC's first launch of 1993.

BY ROELOF L. SCHUILING
At the Kennedy Space Center

The primary objective of STS-54 was the deployment of the fifth Tracking and Data Relay Satellite (TDRS-F) to reach orbit. TDRS satellites now on-orbit provide data transmission and relay services not only to NASA Space Shuttles but also to the constellation of scientific satellites circling the Earth. The STS-54 TDRS-F was delivered to the Kennedy Space Center in September for prelaunch processing and mating with the Inertial Upper Stage booster (IUS). The IUS was also delivered to KSC in September of 1992. The TDRS-F was produced by TRW in Redondo Beach, California for NASA's Goddard Space Flight Center, and the IUS-13 was produced by the Boeing Aerospace Company in Seattle, Washington for the US Air Force who manage the IUS program.

In the Vertical Processing Facility, workers are installing an Inertial Upper Stage (IUS) booster in a test cell. The IUS is used to push the Tracking and Data Relay Satellite into geosynchronous orbit following deployment from the Space Shuttle. *NASA*



In the orbiter's payload bay were two Diffuse X-Ray Spectrometers (DXS) instruments, designed to determine the wavelength and intensity of the strongest X-ray lines emitted by stellar gases. The gases are released when stars, at the end of their life cycles, explode and create supernovas that release hot plasmas.

Endeavour's preparations for STS-54 began with its landing following the STS-47 mission. Endeavour was rolled into the KSC's Orbiter Processing Facility's Work Bay One on September 21, 1992 and remained in the OPF until November 23 as it underwent preparations for this mission which included the installation of the two Diffuse X-Ray Spectrometer instruments on opposite sides of the forward payload bay. Endeavour was mated to its External Tank and Solid Rocket Boosters in the KSC Vehicle Assembly Building on November 23 and underwent checks to verify the interfaces between the orbiter and the other Shuttle components. On December 3, after waiting for the STS-53 launch of Discovery from the adjacent Launch Complex 39A pad on the previous day, the STS-54 shuttle was moved to Launch Complex 39B. The TDRS-F satellite had arrived at the launch pad on November 10 and was installed in the orbiter's payload bay on December 4.

The afternoon of January 10 saw the arrival of the STS-54 flight crew from Johnson Space Center. The countdown clock for the STS-54 mission started at 1:00 pm on January 10 at the T-43 hour mark. At the T-27 hour point, the countdown entered its first built-in-hold of four hours during which the launch crews completed final preparations for loading the fuel cell reactants.

The countdown entered a built-in-hold at 5:00 am on January 12 at the T-11 hour point. While other built-in-holds are usually of standard lengths, the T-11 hour hold - sometimes called the "long hold" - may vary from mission to mission as it is timed to bring the final minute count at the T-0 point to the correct minute count at the desired launch time. For STS-54 this built-in-hold was planned for 12 hours and 32 minutes which, with the two 10 minute holds in the final hour, would bring the count to T-0 at 52 minutes after the hour - the planned launch time. After the T-11 hour hold preparations con-

tinued on schedule.

After breakfast the crew received briefing on worldwide weather conditions from Mission Control in Houston and left for the launch pad aboard their "transfer van" at about T-3 hours, arriving at the "white room" at the end of the access arm about 6:00 am.

At T-1 hours the crew and the launch team received another weather briefing and the weather looked good for the launch. The countdown was not without concerns however. Launch crews dealt with a backup heater failure on the air-conditioning system, helium signature traces in the External Tank Interstage area and an overfilled drinking water tank. A further issue was an upper wind condition that was slightly over limits for a "worst-case" scenario involving the loads on several wing struts if the orbiter were to experience an engine failure precisely as it was at the Mach 1.5 point in its ascent. Analysis of the projected loads and flight conditions continued during the final period of the countdown.

The final ten minute built-in hold at the T-9 minute point was extended approximately seven minutes in order to complete a thorough review of the upper wind loads condition. It was necessary to insure that all shuttle management and operations personnel understood the reasoning involved before resuming the count for the final nine minutes.

TRW technicians are seen inspecting TDRS-6 before it was shipped to Cape Canaveral to begin launch preparations. *TRW*

As the STS-54 countdown resumed, the Ground Launch Sequencer began computerised final countdown activities. At T-31 seconds the Endeavour's internal computers got the "go" to start their own terminal countdown sequence. At approximately T-6.6 seconds the main engines started and at T-0 the Solid Rocket Boosters ignited and simultaneously the booster rocket's explosive bolts fired to separate the STS-54 Shuttle from Launch Complex 39B.

The ascent into orbit followed the planned timeline with Solid Rocket Booster cutoff and separation at 2 minutes 5 seconds into the flight and main engine cutoff at 8 minutes 37 seconds mission elapsed time. External Tank separation came 12 seconds later.

During its ascent, Endeavour shut down one of the three Auxiliary Power Units early as temperatures in the cooling oil system were above normal. This constituted no hazard as the other two units were operating well and the units are not used on-orbit. After the launch Shuttle Operations Director Brewster Shaw indicated that the most likely cause was an ice buildup in the cooling system and that this would provide no concern as the ice would melt or sublimate away in space prior to the unit's next use on landing.

At 39 minutes 55 seconds into the mission Endeavour performed an Orbital Manoeuvring System burn of about 2 minutes 24 seconds to circularise the orbit at approximately 160 by 162 nautical miles with a 28.45 degree angle of inclination. STS-54 was ready to begin its mission.

Flight Day One

The deployment of the IUS/TDRS combination was the first major activity of STS-54. At 3:12 pm (all times are based on KSC's timezone) Mario Runco activated the deployment mechanism and the communications satellite and its booster were eased away from the payload bay by a set of powerful springs. Mission commander John Casper then moved the Endeavour away from the spacecraft before firing the orbiter's manoeuvring engines to move to a safe distance before the IUS engine was fired.

Control of the IUS was taken over by the US Air Force Space Control Facility in Sunnyvale, California. The first stage of the IUS engine burn came shortly after 4:12 pm and lasted about 151 seconds. TDRS-IUS separation occurred shortly after 10:00 pm. IUS controllers reported all engine firings were normal and the TDRS spacecraft was in geosynchronous orbit.

The Diffuse X-ray Spectrometer (DXS) instruments in the payload bay were activated and began taking science data on orbit 7 but on orbit 10 the

The Space Shuttle Endeavour gets NASA's 1993 launch schedule off to a rousing start with a flawless liftoff at 8:59:30 am, EST, January 13, from Launch Pad 39B. *NASA*

starboard instrument experienced problems with high radiation counts and high voltage and the instrument's systems automatically shut down to protect the detectors. Consequently in place of DXS operations the crew performed tests to evaluate the effectiveness of the Shuttle's star trackers to help in the alignment of the onboard navigation system by pinpointing specific stars through the upper layers of the Earth's atmosphere.

Flight Day Two

The science data timeline was resumed on orbit 19 although radiation counts were still higher than expected. The DXS instruments then continued to operate throughout the mission.

Susan Helms worked with the Commercial Generic Bioprocessing Apparatus (CGBA) which collects information on various biomaterials in 28 investigations. Operations began with the Physiological and Anatomical Rodent Experiment (PARE) and the Chromosome and Plant Cell Division In Space Experiment (CHROMEX) as well.

Flight Day Three

The crew took time out for an orbital press interview with radio station WOR in New York. They were asked about the new Waste Containment System which was making its first flight on STS-54 and was performing well.

Other activities during the day included using the Solid Surface Combustion Experiment (SSCE) to burn a small piece of Plexiglas to determine combustion characteristics in microgravity. This experiment has flown on a number of other Shuttle missions and is planned to fly on several more.

The crew also activated an experiment which was designed to examine fluid and nutrient flow through a rotating chamber. This device will be flown on a later Shuttle mission carrying cancer cells. In ground laboratories these cells tend to move out of the nutrient and impact the chamber walls, but in space the cells remain suspended in the fluid allowing full development without disturbance.

The atmospheric pressure in the cabin was lowered to 10.2 psi in order to reduce the level of nitrogen in the bloodstreams of Mario Runco and Greg Harbaugh in preparation for their spacewalks scheduled for Flight Day Five.

Crew members took part in a series of physics experiments with students from schools in New York, Ohio, Michigan and Oregon. The experiments were televised and the crew answered questions from the students.

Flight Day Four

Mario Runco and Greg Harbaugh checked out the EVA spacesuits which they planned to wear for the spacewalk scheduled for the following day and reported that the suits were in good condition.

The astronauts took photographs to add to the collection of Earth surface photographs which have been returned since the early 1960s. The photos are catalogued by the Earth Observation Project at the Johnson Space Center, which provides a liaison to various ongoing scientific research efforts around the world, and enables Shuttle crews to record features of interest to scientists. (See ***Spaceflight***, January 1993, pp.27-30 for details).

TDRS ground controllers reported that TDRS-6 (after achieving orbit TDRS-F was redesignated TDRS-6) was being moved to its checkout position southeast of Hawaii at a rate of 2.9 degrees of longitude per day. Following successful checkout, the TDRS-6 would be moved to its position of 62°W.

Flight Day Five

The EVA scheduled for Flight Day five was the first in a planned series of spacewalks to be performed during the remaining three years leading up to the on-orbit assembly of the Space Station in 1996.

Mario Runco and Greg Harbaugh left the Endeavour's payload bay airlock hatch at about 5:50 am, about 40 minutes behind the planned schedule as the donning of their spacesuits and preparation of the gear had taken somewhat longer than planned. They performed a variety of tasks designed to define the differences between spacewalks on-orbit and simulations in training on the ground. The two climbed back into Endeavour's airlock at 10:11 am.

Crewmembers

The five-member crew included four veteran astronauts who had each flown once before. John H. Casper, 48, Col. USAF was commander of Endeavour's third flight and had flown as pilot on Atlantis' STS-36 mission in February 1990 and was selected by NASA in May 1984.

The pilot for STS-54 was Donald R. McMonagle, 38, Col., USAF who had flown as mission specialist aboard the 8-day April 1991 STS-39 flight of Discovery. He was selected by NASA in June 1987.

Mission Specialist-1 was Gregory J. Harbaugh, 35, a civilian who went to work, at NASA in Houston following his graduation from college in 1978. He was selected as an astronaut in June 1987 and later flew on STS-39 also.

Mission Specialist-2 was Mario Runco, Jr, 39, Lt. Cdr., USN. A former New Jersey State Police trooper, Runco too was selected as an astronaut by NASA in June 1987 and served as mission specialist on STS-44 in November 1991.

Mission Specialist-3 was Susan J. Helms, 33, Major, USAF. She was selected as an astronaut in January 1990. STS-54 was her first space flight.

Due to the late start the spacewalk was slightly shorter than planned; however, the majority of the planned tasks were accomplished. Flight controllers chose to end the spacewalk at the previously planned time despite the late start in order to allow work with the DXS instruments to continue. One of the mission rules governing this, and the upcoming spacewalks in the series, makes the EVA activity lower in priority than the experiment operations, and prohibits an EVA from impacting major experimental activities.

The DXS instruments, after undergoing heating and flushing of their P-10 gas (a mixture of argon and methane), were providing good science data. The DXS team and the Houston Mission Control Center personnel worked together to reschedule mission time to provide the DXS instruments with additional observing time. Because there had been periods during the mission when DXS had not been planned to operate, controllers were able to provide up to 15 additional orbital opportunities for DXS observations. By this time the DXS science team was reporting high quality data that was as good as that anticipated before the flight. The port instrument appeared to be yielding data with greater than anticipated efficiency. This was felt to be due to the instrument's electron rejection magnets doing a better job in screening out electron contamination from the Earth's radiation belts than had been expected.

Flight Day Six

On their final full day in space the crew shut down one of Endeavour's electricity-producing fuel cells. This was a step in certifying the orbiters for long duration periods while docked to the Space Station later this decade. Shutting down the fuel cells will be a routine occurrence in the Space Station operational era since the electricity for the Shuttle orbiter can be provided by the station without using up the orbiter's fuel cell reactant supply. The operation went as planned with the number 2 fuel cell being shut down during the period when the orbiter was undergoing its checks and tests for the landing during much of the day. Both shutdown and restart went well.

Reaction jet firings and systems tests as well as CGBA deactivation and stowage operations took up much of the day. Preparations for landing envisioned two possible landing opportunities for Endeavour at the Kennedy Space Center; one at 7:02 am on orbit 95 and one at 8:38 on orbit 96.

Flight Day Seven

Due to a shallow ground fog on the KSC runway, flight controllers chose to take the second of KSC's landing opportunities on the morning of January 19. About an hour before the landing Endeavour fired its manoeuvring engines to slow its speed and begin its descent. Re-entry and approach went well. The orbiter passed high over the Kennedy Space Center in the morning sunlight and began a sweeping right turn that took it out over the Cape Canaveral Air Force Station and the Atlantic Ocean before curving back to line up with KSC's runway 33. Touchdown came at 8:38:17 am approximately 1,500 feet from the runway's threshold. The orbiter rolled approximately 8,700 feet before stopping.

By 2:00 pm Endeavour was back in the Orbiter Processing Facility's work bay one for deservicing and for the preparations which will lead to its next mission: STS-57.

TDRS Spacecraft Launch and Operational Status

Spacecraft	*Mission*		*Functional Status*	*Longitude before/after TDRS-F launch*
TDRS-1	STS-6	Apr 5, 1983	Partial	171°W/85°E
TDRS-2	STS-51L	Jan 1986		
TDRS-3	STS-26	Sep 29, 1988	Partial	62°W/171°W
TDRS-4	STS-29	Mar 13, 1989	Full	41°W/41°W
TDRS-5	STS-43	Aug 2, 1991	Full	174°W/174°W

SATELLITE DIGEST-250

Satellite Digest is our regular listing of world space launches. It is based upon a more detailed monthly satellite listing published by the Molniya Space Consultancy prepared by Phillip S. Clark.

Spacecraft	Int'l Desig.	Launch	Launch Site	Launch Vehicle	Mass kg	Orbital Epoch	Inclin. deg	Period min	Perigee km	Apogee km	Notes
Superbird A1	1992-084A	Dec 1.95	Kourou	Ariane 42P	2,780	Dec 12.34	0.09	1,436.09	35,759	35,814	1
Molniya-3 43	1992-085A	Dec 2.08	Plesetsk	Molniya	1,750 ?	Dec 14.47	62.83	717.77	416	39,939	2
STS-53	1992-086A	Dec 2.57	KSC	Discovery	87,565	Dec 3.85	57.00	91.01	318	331	3
DOD-1	1992-086B	Dec 2.57			10,530	Dec 3	57	91.9	370	370	
Cosmos 2223	1992-087A	Dec 9.48	Tyuratam	Soyuz	7,000 ?	Dec 10.21	64.66	89.85	241	293	4
Cosmos 2224	1992-088A	Dec 17.53	Tyuratam	Proton-4	2,200 ?	Dec 17.51	2.30	1,448.43	35,877	36,179	5
Navstar 17	1992-089A	Dec 18.94	ER	Delta-2	1,667	Dec 31.32	54.75	717.98	20,040	20,325	6
Optus-B 2	1992-090A	Dec 21.47	Xi Chang	CZ-2E	7,650 ?	Dec 21.79	28.13	97.14	208	1,036	7
Cosmos 2225	1992-091A	Dec 22.50	Tyuratam	Soyuz	6,500 ?	Dec 23.61	64.91	89.73	214	309	8
Cosmos 2226	1992-092A	Dec 22.53	Plesetsk	Tsyklon-3	1,000 ?	Dec 23.23	73.63	116.03	1,479	1,526	9
Cosmos 2227	1992-093A	Dec 25.25	Tyuratam	Zenit-2	9,000 ?	Dec 26.30	71.02	101.96	849	854	10
Cosmos 2228	1992-094A	Dec 25.84	Plesetsk	Tsyklon-3	2,000 ?	Dec 26.17	82.53	97.75	633	669	11
Cosmos 2229	1992-095A	Dec 29.56	Plesetsk	Soyuz	6,000 ?	Dec 29.86	62.81	90.45	218	376	12

NOTES

1 Superbird is a Japanese satellite, operated by Space Communications Corporation, Tokyo and used for domestic communications in Ku- and Ka- bands. Satellite body is a box 3.4 metres high, 2.4 metres x 2.2 metres with a solar panel span of 20.3 metres after deployment. Mass given above is at launch: on station the mass is 1,665 kg and at the end of its operating life the mass should have dropped to 1,255 kg. Deployed over 158°E. Actual launch time was 22.48 GMT.

2 Communications satellite, co-planar with Molniya-3 34. Shape is cylindrical body, 1.6 metres diameter, 3.6 metres long with six vanes of solar panels deployed to give a windmill appearance.

3 First flight of shuttle orbiter Discovery after refurbishment. Crew comprised D M Walker (commander), R D Cabana (pilot), G S Bluford (mission specialist, MS-1), J S Voss (MS-2) and M R Clifford (MS-3). Orbiter has a body diameter of 5.5 metres, body length 37 metres and wingspan 23.8 metres: mass given above is that projected for landing. Launch was at 13.24 GMT and landing at Edwards Air Force Base was 20.44 GMT. Primary payload was DOD-1, the final primary Department of Defense classified payload to be carried into orbit by the space shuttle. Mass quoted above includes support equipment which remained in the shuttle orbiter's payload bay. USSPACECOM has not released orbital data for DOD-1 and that quoted above is taken from the Rockwell International STS-53 Press Information publication. Landed December 9.86.

4 Payload is fifth generation photoreconnaissance satellite, expected to remain in orbit for seven months or more. Design details unknown, but probably cylindrical (diameter 2.3 metres, length 7 metres ?) with a spherical re-entry capsule. Similar Cosmos 2183 (1992-018A), launched 1992 April 8, still operating as Cosmos 2223 began its mission.

5 Cosmos 2224 is fourth satellite in the Prognoz remote sensing series, previous satellites having been Cosmos 1940, Cosmos 2133 and Cosmos 2209. The latter two satellites are currently operating over 336°E. No description of this class of satellite is available. As of 1993 January 4 the satellite was still drifting in an orbit close to the one listed above.

6 Eighth flight of Block 2A Navstar satellite. Satellite is a cylinder plus four vanes: approximate dimensions 2.4 metres long, 1.8 metres diameter and a span of 5.3 metres. Mass quoted above includes propellant: dry mass is 844 kg. Actual launch time was 22.28 GMT.

7 Optus-B 2 is an Australian communications satellite, previously known as AUSSAT-B 2: launched by Chinese as a commercial venture. Satellite is a Hughes HS-601 model. Central body of satellite a box 2.3 metres on each side with a solar panel span of 22 metres (if they are deployed). Dry mass of satellite 1,272 kg: propellant mass approximately 1,700 kg. Satellite should have been deployed close to 160°E. The above mass assumes that the complete satellite reached orbit, although it is clear from debris found under the ascent path that at least part of the satellite was destroyed during the ascent. Although delivered to the correct orbit, the third stage failed to fire, probably because of the damage which it and the satellite sustained during the journey to orbit. Actual time time was 11.20 GMT.

8 Fourth generation photoreconnaissance satellite belonging to either the topographic/mapping sub-group (lifetime about 45 days) or a new special sub-group first flown in 1989 (lifetime about 60 days). Details of the satellite design are unknown.

9 Geodetic satellite in the GEO-IK series. Design apparently based upon the Tsikada-class navigation satellites. Cylinder, approximately 2 metres diameter and 2.1 metres long plus gravity-stabilising boom plus ten vanes of additional solar panels deployed.

10 Second successful launch of Zenit-2 booster in five weeks after three successive failures. Satellite is believed to be an ELINT payload, details of which are unknown. Orbital plane is 90° away from Cosmos 2219, launched 1992 November 17, and is identical with the orbital plane intended for the failed launches in 1990 October and 1991 August. Zenit second stage disintegrated soon after satellite deployment - the first disintegration of a Zenit rocket body in orbit.

11 Cosmos 2228 believed to be a small Worldwide ELINT satellite, the appearance of which is unknown. Co-planar with Cosmos 2058.

12 Tenth Bion biological satellite to be launched. Carried two monkeys, plants and insects: payload included ESA's Biobox experiment. Spacecraft design based upon the original Vostok craft: sphere cylinder with a diameter of 2.4 metres and a length of 5.9 metres. Descended on 1993 January 10. Orbital data of spacecraft at time of recovery still awaited as this Table is closed for publication: similarly, the decay notice for the Soyuz third stage had not been issued through to 1993 January 5.

ADDITIONS AND UP-DATES

1978-024D Molniya fourth stage from Molniya-1 39 launch decayed from orbit 1992 Dec 11.

1980-002F Molniya fourth stage from Molniya-1 46 launch decayed from orbit 1992 Dec 4.

1987-040A Gorizont 14 has been rediscovered by USSPACECOM after being lost in June-July 1992. It is now drifting in the following orbit - 1992 Nov 22.68, 5.87°, 1,474.55 minutes, 36,406 km, 36,667 km, 249°.

1991-072A Cosmos 2164 decayed from orbit 1992 Dec 12.

1992-054B CZ-2E second stage from Optus-B 1 launch decayed from orbit 1992 Dec 12.

1992-081B Molniya third stage from the Cosmos 2222 launch decayed from orbit 1992 Dec 28.

International Space Report

Launch Failure 'Not Rocket Carrier'

BEIJING - An investigation into the launch failure of a US-built Australian satellite on 21 December 1992 has found that the Chinese carrier rocket operated normally and was not to blame. The satellite, manufactured by Hughes Aircraft Company and owned by the Australian-based firm Optus Communications, was launched aboard a Long March 2-E rocket from China's Xichang Space Centre in southwest Sichuan Province.

The rocket appeared to place the Optus B-2 satellite in orbit but a small explosion had occurred and the satellite broke up. The report said the explosion occurred in the satellite vehicle itself about 45 seconds into the launch. It did not speculate on a cause, but said the outcome indicated "the performance of the Chinese rocket is very reliable". Chinese officials had worked feverishly since the incident to pin the blame on something other than their rocket, fearing a major embarrassment to the country's fledgling commercial space programme.

Launch Failure was 'Faulty Engine'

CAPE CANAVERAL - A faulty engine valve caused the Atlas launch failure of August 1992 and most likely also caused the first failure in April 1991, according to General Dynamics Corporation. After the second failure in August 1992, General Dynamics put the launcher on hold. In financial terms the combined losses topped $250 million.

In both cases, the rockets began to tumble and had to be blown up six to eight minutes after liftoff from Cape Canaveral, with the loss of their communications satellites.

With the problem now identified, General Dynamics Space Systems said Atlas flights will resume in March. The valve in one of the upper-stage Centaur rocket engines failed to close before liftoff, allowing air into that engine during ascent. The air then solidified in the liquid hydrogen fuel pump, preventing the engine turbine from rotating. Extra valves are being added to Centaur engines, which are built by Pratt and Whitney, as a safeguard.

Tracking Cars from Space

LONDON - Researchers at the Ford Motor Company Dunton Engineering Centre are working on a low-cost device that will tell you exactly where your car is after it has been stolen. Or if you are on the hard shoulder of the motorway with a mechanical breakdown and there is no phone in sight you just push a button and the emergency services are on their way.

The company believes the system could be ready for use in five years and tests are currently underway with a prototype vehicle in Essex, southern England. The system combines mobile telecommunications technology with the Global Positioning System (GPS) of satellites set up by the US military.

In operation, a driver would use a control on the dashboard to select from a choice of services such as breakdown, police, ambulance or fire which are displayed on small displays. At the push of a button, a message is transmitted to a base station detailing the make and model of the car, its registration number and its position within five yards (metres). In case of breakdown, the message could also include details from the vehicle's diagnostic system about the faults. Within seconds of sending the message, the driver will see the expected arrival time of the services on his dashboard.

In case of car theft, the police could contact the base station with a vehicle identification number and the owner's personal identification number. The base station can then track down the vehicle and, if the stolen car is moving, police can be constantly updated about its position.

Air Breathing Rocket

ALL INDIA RADIO reports that the Indian Space Research Organization has achieved a significant breakthrough by successfully test-firing an Air Breathing Rocket ABR-200. According to Dr Manoranjan Rao of the Vikram Sarabhai Space Centre, the rocket will be able to carry a much higher payload when the technology becomes operational.

'Marsokhod' Test

MCDONNELL DOUGLAS is conducting a series of tests to evaluate a Russian-built six-wheeled prototype planetary rover. A Russian team which operated two unmanned "Lunakhod" rovers on the Moon's surface in the 1970s is now preparing a 'Marsokhod' vehicle for the upcoming Russian Mars '96 mission. The Russian team consisting of representatives from the Russian Academy of Science's Space Research Institute (IKI), the Babakin Centre (the primary supplier of interplanetary spacecraft for the former Soviet Union) and the Mobile Vehicle Engineering Institute (VNIITransmash) brought a prototype rover to the United States for testing in Huntington Beach. McDonnell Douglas Aerospace is looking to develop closer ties with leading space organisations of the former Soviet Union. While the upcoming efforts will focus on rovers, McDonnell Douglas Aerospace intends to investigate other possible areas of future collaboration.

A New Ariane 5 Contract

AVICA EQUIPMENT, Hemel Hempstead, which is the UK's only company contributing to the Ariane 5 space programme, has won a new contract to manufacture components for the EPS propulsion system. The agreement with MBB Space Transportation Systems & Propulsion division is for high performance gimbals joints. The initial development contract is for 90 units.

Avica, a division of Meggitt Aerospace, part of Meggitt plc, has already been awarded a four year, multi-million pound contract by the French company Societe Europeenne de Propulsion (SEP) to manufacture fuel and hot gas ducting for Ariane 5. Avica has been involved in all the Ariane programmes and has been on Ariane 5 since 1986.

Space Radars Study

GEC Ferranti Defence Systems, Milton Keynes UK, which will form part of GEC-Marconi Avionics, has won a £250,000 study contract from the UK Defence Research Agency at Malvern to investigate architectures for space-based radars.

The company will be the prime contractor, working with Matra Marconi and the GEC Marconi Research Centre at Great Baddow. Responsibility for the contract at Milton Keynes will fall to the Advanced Technology Laboratory and the Special Projects Department.

UK Firm to Build ESA Satellite Spectrometer

CHISLEHURST, Kent. Sira, the UK instrumentation technology and space hardware company, has been awarded a contract by ESA for the third phase of MERIS (the MEdium Resolution Imaging Spectrometer project), which is the world's first remotely-programmable imaging spectrometer designed to be operated on an Earth-orbiting satellite. The award follows detailed design and prototyping work by Sira as part of an international team headed by Aerospatiale, reporting to ESA's prime contractor, Dornier Systems.

MERIS will be central to ESA's first Polar Earth Observation Mission (POEM 1), which will monitor the environment on a global scale providing complete coverage of the Earth every three days.

The spectrometer is programmable in flight from the ground, allowing it to undertake a general monitoring role or focus on a particular environmental concern when it arises. It differs from earlier instruments, such as SPOT, LANDSAT and CZCS, in that preselection of spectral bands is not necessary.

Scheduled for launch on the European Polar Platform (ENVISAT) in 1998, MERIS will image the Earth in the visible and near-infrared wavebands with a ground resolution of 250m and a spectral resolution of 1.25nm.

This combination of spatial and spectral ranges makes MERIS ideal for detailed water quality and land measurements, such as plankton content of sea-water, depth and bottom-type classification, monitoring of extended pollution areas and synoptical monitoring of vegetation. There is also interest in deriving atmospheric data from the output of MERIS.

The final construction phase of the MERIS project will take the spectrometer through structural, engineering and qualification models to the final flight model stage. Flight models and spares have been timetabled for delivery in mid-1996.

New Structure for Ariane 4

BRITISH AEROSPACE SPACE SYSTEMS, Stevenage, UK has delivered to Arianespace the first protoflight Mini SPELDA. SPELDA (Structure Porteuse Externe Lancement Double Ariane) is the French acronym for "Structure for double launch capability on Ariane 4".

SPELDA is an integral part of the external structure of the launch vehicle and provides the largest internal usable volume at minimum mass. It was initially developed under an ESA contract between 1982 and 1986 with the initial production of six being delivered between 1985 and 1989. Between 1986 and 1989 the SPELDA Improved Programme (SIP) led to significant improvements to the design and production methods. In 1987 Arianespace and British Aerospace Space Systems signed a Memorandum of Understanding for the production of 20 SPELDAs. British Aerospace is currently working on the final batch and looks forward to further orders.

The original and subsequent SIP programmes covered the development of Short and Long SPELDAs. During 1990, Arianespace saw an opportunity to add a Mini version to the programme to significantly enhance the flexibility of Ariane 4. British Aerospace was selected to develop Mini SPELDA in January 1991.

The first flight using the Mini SPELDA, Ariane 4 Flight V58, is scheduled to take place in May when the new structure will house the Insat 2B satellite inside and support the Hispasat 1B satellite on top.

Propulsion Module Tests

MCDONNELL-DOUGLAS. During the space shuttle's second space station assembly flight, two propulsion modules will be positioned on Freedom. Two more will be added following mantended capability, and an additional pair prior to permanent manned capability.

Early modules will have 13 thrusters, located at both ends and on the top of each module. On later modules the number of thrusters will be scaled down to nine. The thrusters can be fired independently, allowing precise positioning of the station.

Static firing test of propulsion development units has now begun at NASA's White Sands Test Facility in New Mexico with units having 10 small thrusters, each with an operational range of 9 to 25 pounds thrust, and three large thrusters with 20 to 55 pounds thrust.

Eureca Retrieval

ESA, Paris - Within five months of its launch on 31 July 1992, more than three quarters of the planned experiments on-board Eureca had been successfully completed and the remainder should be completed by mid-February 1993.

The satisfactory progress of the mission proves the underlying concept of operating a complex space research facility by means of satellite autonomy and on-board operations that are preprogrammed and controlled during scattered daily control centre contact times totalling only around 5% of the duration of the mission on average.

Eureca, currently orbiting at an altitude just below 500 km, is to be retrieved together with its experiments and samples, at the beginning of May 1993 by Endeavour on flight STS-57.

The Eureca mission's output consists of experimental data that is sent regularly to the ground for scientific and engineering analysis, materials processed in the very low residual gravity that is offered by the Eureca mission, samples exposed to space, surface forces research, space particle collection and new technology applications.

While a significant portion of the mission's yield is contained in its abundant and continuous data generation, the primary mission objective is the analysis in ground-based laboratories of biological and material samples and the ability, in principle, to reuse the spacecraft and payloads again in a later flight.

To date, more than 122,100 data requests (on average around 800 per day) from various remote locations/investigators (experiment home institutes, DLR's Microgravity user Support Centre, industry and ESTEC) have been served by the Eureca Data Disposition System (DDS) at ESOC, using mainly packet switching public data networks (PSPDNs) to transmit a total data volume in excess of 6000 million bytes (on average around 35 Megabytes per day).

Astronaut Chief

NASA - Robert "Hoot" Gibson has been named chief of the 89-member astronaut corps replacing Dan Brandenstein, who left the space programme in October 1992. Gibson, who became an astronaut in 1978, has commanded three shuttle flights, the most recent in September 1992 and served as shuttle pilot once. His wife, Rhea Seddon, is also an astronaut. Loren Shriver, who has flown in space three times, has been named deputy chief astronaut.

Space Mirror Test

MOSCOW - A 20-metre wide mirror made of Kevlar coated with a thin layer of aluminium and shaped like a parachute was successfully unfurled from a rotating Progress spacecraft in orbit close to the Mir space station at 7:53 pm (EST) on 3 February. The experiment, which lasted 6 minutes, was the first tentative step in a project to provide nighttime illumination for polar areas. At the end of the experiment the reflector was detached from the spacecraft and destroyed on re-entry.

Since the reflective banner was orbiting the globe, the spot on Earth moved quikly across Europe toward the former Soviet Union.

Two UK Institutes Join ISU

OXFORD - The Extreme Environments Laboratory (EEL) and the Oxford School of Architecture of Oxford Brookes University are to become an affiliated campus to the ISU (International Space University) for Space Architecture.

The Cranfield Institute of Technology, with its partners, has likewise won affiliation for the Space Physical Sciences.

A permanent site has been selected for the Central Campus of the International Space University at Strasbourg and is to be in operation by 1995-96.

An advanced communications system, known as ISUNET, will link the ISU Central and Affiliate Campuses electronically with world space agencies and industry providing instant access to the leading scientists, engineers and space-related projects in the world.

Radar Altimeter for ERS-2

ROME - The radar altimeter for the ERS-2 Earth observation satellite of the European Space Agency has been delivered by Alenia Spazio to Dornier (DASA Group). The launch of ERS-2 is expected sometime in 1994 and is part of the Earth surface observation mission which began in 1993 with the launch of ERS-1.

The radar altimeter which was developed by Alenia Spazio and installed on the ERS-1 is performing very well in observing both the ocean surface (topography and condition) and the polar ice sheets.

Alenia Spazio has also been given a contract worth about 100 billion lire for a radar altimeter to be installed on board ESA's ENVISAT satellite which is due to replace the ERS series.

SPACE AT JPL

Radar Observation of Earth

BY DR WILLIAM I. McLAUGHLIN
Jet Propulsion Laboaratory, California, USA

The great value of radar observation of Earth from orbit was clearly affirmed in 1978 by results from Seasat. The SIR-A and SIR-B missions employed radars derived from Seasat in their November 1981 and October 1984 shuttle flights, respectively. See the February 1985 edition of this column for a report on SIR-B. Originally "SIR" denoted "shuttle imaging radar"; now the "S" stands for "spaceborne." A higher-frequency radar developed by Germany, the Microwave Remote Sensing Experiment (MRSE), was flown on the first shuttle-Spacelab mission in 1983. Now, the U.S., Germany, and Italy are partners in the joint SIR-C/X-SAR shuttle-based mission to go aloft in late 1993 or early 1994.

The etymology of "SIR-C/X-SAR" can be unraveled by first looking at "SIR-C"; it is historically based, being the third in the series (fourth if Seasat is counted), and represents the U.S. contribution to the joint project.

The "X-SAR" root represents the European contribution and is a technically focused term in that "X" denotes the wavelength region, "X-band", about 3 cm, of the microwave domain utilized by this instrument. "SAR" stands for "synthetic aperture radar".

"Synthetic aperture" is a reference to the synthesis, through the orbital motion of the shuttle, of a larger antenna aperture than the physical device presents. The U.S. and European radars each are SARs as was the radar utilized by Magellan in its mapping of Venus. Dr. Charles Elachi is an Assistant Laboratory Director at JPL and manages the Office of Space Science and Instruments. He has been instrumental in bringing SARs to bear on problems in Earth science. See his "Radar Images of the Earth from Space" in the December 1982 *Scientific American*.

For spaceborne radars, pulses of microwave energy are bounced off Earth and the backscattered signal, collected by the spacecraft's antenna, carries scientific information about the scatterer: the Earth's surface. The thoroughness of probing of the surface is increased by exercising more features of the electromagnetic spectrum. Three primary characteristics of the radiated energy are available for manipulation by the investigator: frequency, polarization, and angle of incidence on the Earth's surface.

The three frequencies available to SIR-C/X-SAR are, expressed in terms of wavelength, L-band (23 cm) and C-band (6 cm) for SIR-C, and X-band (3 cm) mentioned above for X-SAR.

Polarization, which imposes constraints on the vibrations of the electromagnetic field comprising the microwave transmission, is "vertical" (V) or "horizontal" (H). The two radar frequencies of SIR-C can each assume four polarization states, HH, VV, HV, and VH, while X-SAR will be used in the VV-polarization mode. Thus, in effect these are 2 x 4 + 1 = 9 radars available for scientific investigations, and, moreover, these mine channels can be used simultaneously, wherein 10KW of radio-frequency power is required. The Seasat and SIR-A radars were constrained to glance off the Earth at one fixed angle. On SIR-B it was possible to vary the angle of incidence in order to obtain more information. The directions of the beams for the SIR-C radars are electronically steerable, while X-SAR changes direction through mechanical rotation of the antenna.

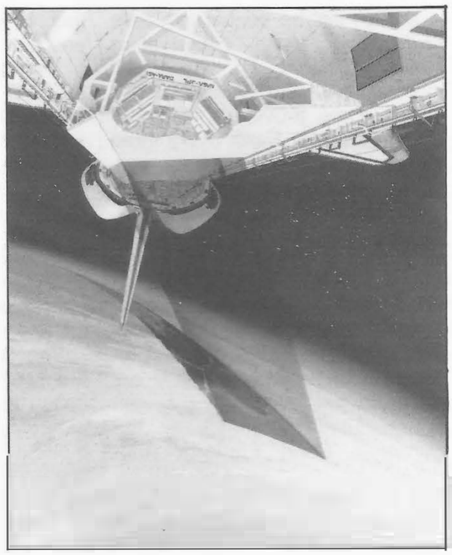
The flight of SIR-C/X-SAR will result in the collection of 50 hours of data, which corresponds to about 50 million square kilometres of ground coverage. The U.S. Project Manager, Michael J. Sander of JPL, commented to me that radars are so prolific in the production of data that they can "drench you up to the waist in bits". In particular, he was thinking ahead to the EOS-SAR ("EOS" stands for "Earth Observing System") mission of NASA which is scheduled for launch about the year 2000.

Hence, Sander remarked, one of the prime objectives of SIR-C/X-SAR is the development of algorithms for data processing. This development is facilitated by 19 "supersites", spread through the Americas, Europe, Africa, and Australia, where measurements taken from the satellite can be calibrated with *in situ* observations by investigators present at these sites. The goal is to develop algorithms which allow *quantitative* evaluation of observations in terms of the backscattered signal received at the satellite.

For example, one would like to be able to estimate the amount of biomass in the form of trees in a region in order to compute the amount of carbon captured by trees. (Recall that knowledge of the quantity of carbon dioxide present in the atmosphere is key to any predictions concerning the "greenhouse effect", and plants utilize carbon dioxide as an input to their metabolic processes.) In support of this particular measurement, a forest at Oberpfaffenhofen in Germany, one of the 19 supersites, was calibrated by measuring the locations and diameters of its constituent trees in order to provide "ground truth".

An important aspect of ecological studies is the evaluation ofthe status of rain forests.

An important ingredient in meteorological studies is the measurement of rainfall on a global basis.



An artist's conception of SIR-C/X-SAR shows this radar system in the bay of the shuttle as it gathers scientific information during an upcoming flight. *NASA/JPL*

Photography of the supersites is already underway on a time- available basis from the shuttle in order to create a reference file which includes more than just radar-frequency data. A NASA DC-8, "AirSAR", has been adding to the file too.

SIR-C/X-SAR itself will generate data at a rate of 180 megabits per second. It is possible to send 50 megabits per second of the data stream through the space link from shuttle to Earth via NASA's Tracking and Data Relay Satellite System (TDRSS). Most of these data will be from X-SAR. The remainder of the radar data (including a backup copy for the X-band set) will be stored on 160 data tapes onboard the shuttle for conveyance to Earth.

The X-SAR contributed by the Europeans employs an elegant graphite-epoxy antenna which is a technological step forward for the state-of-the-art.

The U.S. radar is electronically sophisticated, but no attempt has

been made to produce a light-weight structure. Two years ago, when Sander became project manager, he inherited a complicated, folding design for the SIR-C antenna. The reason for this state was to leave room in the shuttle bay for another payload. However, with the heavy demands of SIR-C/X-SAR on shuttle resources such as power and crew time (the experiment will operate 24 hours a day), it would seem unlikely that a second payload could be accommodated, other than volumetrically. Therefore, it was no loss to change plan and build a solid, massive structure in place of the original design, and the benefit was a reduction in complexity and cost. The SIR-C antenna is the most massive piece of flight hardware ever built at JPL and has a mass of 10,500 kg, dimensioned 12 meters by 4 meters.

The complete scientific program of SIR-C/X-SAR spans several disciplines: geology, hydrology, ecology and vegetation science, oceanography, and meteorology.

Among the geological questions to be addressed are some related to patterns of past glaciation and tectonic history. The ability of the radar to penetrate extremely arid sheets of sand will allow mapping of buried structures, including paleodrainage features.

Water often gives a distinctive radar signature, and, for example, soil-moisture measurements will be feasible as one of several hydrological parameters to be determined.

An important aspect of ecological studies is the evaluation of the status of rain forests. Models will be developed to discriminate between backscatter responses from a canopy of vegetation and the underlying soil. The structure of canopies and the identification of vegetation types are within reach of SIR-C/X-SAR.

The Topex/Poseidon mission launched in August 1992 (see the December 1992 edition of this column) is using a radar altimeter to investigate the patterns of circulation of the oceans, SIR-C/X-SAR observations will complement these measurements, contributing to the theory of wave imaging and internal wave behaviour.

An important ingredient in meteorological studies is the measurement of rainfall on a global basis. SIR-C/X-SAR will undertake a proof-of-concept demonstration of rainfall measurement from space.

The SIR-C/X-SAR mission has three signs of a space classic in the making: good science with an evolutionary track to facilitating even better science; technological advances in an important area; and another notch on the stick of successful international collaborations.

Zones for Planets

Searches for extraterrestrial intelligence are aimed at finding evidence at the high end of the biological scale while searches for extra-solar-system planets probe the basis for biology as we envisage it. Methods of detecting planets about other stars are varied and include not only direct imaging but also indirect techniques such as measuring the "wobble" induced by a planet in the slowly evolving track of a star across the sky. A new method has recently been utilized to analyze the structure of material known to be orbiting certain stars and has found indications that this structure may, in part, derive from imbedded planets.

Earlier in this century, the favoured theory for the origin of the solar system was the tidal hypothesis developed by Sir James Jeans (1877-1946) and Sir Harold Jeffreys (1891-1989). In this scenario, a star passing by chance through the neighbourhood of the Sun drew material from that body through the action of gravitational force. The solar material, rather than falling back to its place of origin, was induced to orbit the Sun and eventually produced the retinue of planets which we know today.

However, subsequent scrutiny was not kind to the tidal hypothesis, and currently the nebular hypothesis holds sway as the root principle of cosmogony. This theory presumes that a portion of a molecular cloud within our galaxy collapsed as a result of gravitational forces within the cloud, forming a protostar. When temperatures rose high enough within the protostar, nuclear reactions were initiated: a star, our Sun, was born. (The philosopher Immanuel Kant (1724-1804) and the astronomer and mathematician Pierre Simon Laplace (1749-1827) had each formulated a version of the nebular hypothesis.)

During the protostar phase, the in-falling material formed a roughly spherical structure enclosing the central object. Later, in the so-called T Tauri phase (T Tauri is a star in the constellation Taurus and serves as a model for low-mass stars in this portion of their development cycle), only a disk of material remained around the Sun. For our Sun, after planetary formation was complete, very little else of the disk remained.

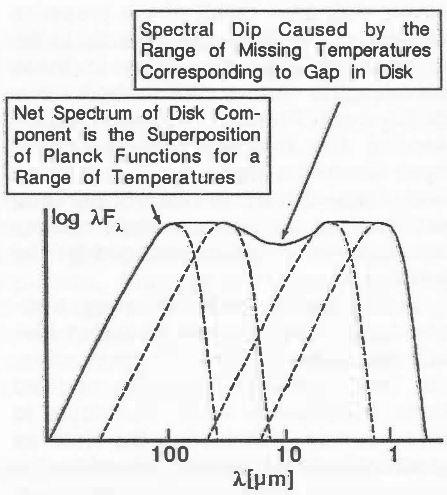
Drs. Kenneth A. Marsh and Michael J. Mahoney of JPL have applied a few basic ideas of physics to thinking about how the process of planet formation, if it were taking place in the circumstellar disk of a T Tauri star, might be observable from the Earth.

The first idea, already extant in the astronomical literature when they began their research, is that a gap in the circumstellar disk would be created as a planet started accreting from the primordial material. Tidal disruption by the growing protoplanet is thought to be the primary mechanism of zone clearing, complemented by gravitational resonance effects between the protoplanet and other circumstellar material.

For the next step in the chain of reasoning, it is necessary to note that temperature decreases in a circumstellar disk with increasing distance from the star. This is intuitively plausible since the disk material is heated by radiation from the star. For the class of T Tauri stars, the temperature fall-off has been estimated to be approximately proportional to the square root of the distance. Thus, if particle A were four times the distance from the star as particle B, A would have a temperature one-half that of B.

Now, one cannot directly measure, as in thermometry, the temperature of a point in a circumstellar disk. However, there is a relation between the wavelengths of light emitted from a particle in the disk and the temperature of that particle, and it is possible to measure the amount of energy being emitted from the whole disk of particles as a function of wavelength. The crucial point of the argument of

Effect of Gaps on Spectral Energy Distributions



The dotted lines outline four illustrative "Planck functions", each of which describes the energy (vertical axis of chart) radiated over a spread of wavelengths (horizontal axis of chart, wavelengths measured in microns) by a particle of matter at a certain temperature. The Planck functions shift to shorter wavelengths (to the right) for warmer particles. For a ring of particles about a star - a circumstellar disk - a gap in the disk would manifest itself as a dip in the energy spectrum as measured from Earth. One cause of a gap might be clearing due to planetary formation. *NASA/JPL*

Marsh and Mahoney is that if the emission spectrum of the disk is seen to be deficient in a region of wavelengths, then, due to the known relationships between wavelength and temperature *and* between temperature and location in the disk, a deficiency in the amount of material can be inferred for certain locations in the circumstellar disk.

To anticipate the "bottom line", Marsh and Mahoney did find likely cleared Zones in the circumstellar disks of two stars, HK Tauri and GK Tauri, and conclude that these may be regions where planetary formation has taken place. However, their analysis was more careful than this summary has indicated, and it is worthwhile to pursue some of these details.

First, as a point of physics, the plural in the phrase "the wavelengths of light emitted from a particle", acknowledges that, unlike a laser, a particle of matter will emit energy with a whole range of wavelengths, i.e., not monochromatic emission. Planck's formula is a mathematical expression which quantifies this fact and shows how the amount of energy emitted at a given wavelength varies with the temperature of the emitting object. The graph of Planck's formula shows a maximum of energy emission which shifts to shorter wavelengths as the temperature of the emitting body increases; a hot stove can glow cherry red, and, as its temperature is increased, the red colour of the glow will become less pronounced. (Red represents the longest visible wavelengths.)

Picture then what happens to the output of energy emission versus wavelength when certain temperature values are not achieved in the circumstellar disk as a result of the presence of clear zones; there will be a dip in the expected amount of energy in those wavelengths where the temperature-dependent Planck formulas representing the missing material would have reached a maximum. It is as if one had removed a whole block of performers from an orchestra: certain characteristic tones would be reduced for the performance.

When Marsh and Mahoney analyzed the spectra (energy output versus wavelength)of two T Tauri stars, GK Tauri and HK Tauri, they modeled three components which contribute to these curves (considering the data as graphically represented): the star, the circumstellar disk, and the boundary layer between star and disk. The boundary layer is a turbulent region due to star/disk interactions, which are exacerbated by differing speeds of rotation, and emits an excess of high-energy, ultraviolet light. Using a mathematical model built from these components, and including in the model a depleted region of the disk ("the gap", "the clear zone": where planets might be abuilding), they were able to reproduce to good fidelity the observed spectra of GK Tauri and HK Tauri by adjusting parameters of the model. The key parameters were the inner and outer radii of the depleted region.

In order to strengthen the case that large orbiting bodies in a circumstellar disk would indeed produce energy dips in a region of the spectrum of the system, Marsh and Mahoney selected two test cases, GW Orionis and DF Tauri, of T Tauri stars that have a known (stellar) companion. The binary nature of GW Orionis had been revealed (R. D. Mathieu, et al. in the *Astronomical Journal*, vol. 101, p. 2184, 1991) through analysis of periodic shifts in its spectral lines. The double star DF Tauri's orbital parameters were obtained through observing the two-step diminution in the brightness of the system during an occultation by the Moon (M. Simon *et al*. in the *Astrophysical Journal*, vol. 384, p. 212, 1992). These two stellar systems showed dips in their spectra which fit the analytical model of Marsh and Mahoney.

The investigators have documented a portion of their work in the *Astrophysical Journal* (vol. 395, p. L115, 1992), and a second paper has been written and is in the review cycle.

The path which lead to their discoveries started from a JPL study as to what kinds of science would be possible from a future lunar base. When considering observations of planets about other stars, Marsh was stimulated to think about what could be done from the surface of the Earth and obtained the central insight. Mahoney said that he played "devil's advocate" to Marsh's idea for several months. But, as the hypothesis survived test after test, both investigators swung over to the role of advocate and the planetary-formation theory emerged.

What is the Problem?

Perhaps all endeavours in science and engineering could be forced into the category of "problem solving", but one should probably leave space for faculties such as "pure invention" and "leadership". In any case, mastery of the art of problem solving is of crucial importance to progress in space programs. The art seems to be innate for many gifted people, but there are stratagems and principles which have been evolved over a long period of time for the purpose of steering through obscurities. It makes sense to view the subject of problem solving as a set of examples along with a theoretical component.

The term "heuristic" has been used to denote a set of techniques with which to address problems. The mathematician George Polya (1887-1985) had a distinguished professional career but made time to supplement his more technical works with a small masterpiece: *How to Solve It* (second edition, 1957, Princeton University Press). By example and by an integrated approach to problem solving, Polya has provided a most useful heuristic for university students and others harried by the necessity "to solve it".

Polya's approach is divided in logical fashion into four phases:

(1) understanding the problem,
(2) devising a plan,
(3) carrying out the plan, and
(4) looking back.

The heart of the issue, devising a plan, includes discussion, for example, of the efficacy of looking at related problems or trying to solve more general or more special cases of your problem.

The basic idea in any problem situation is to look continually at the matter from a series of fresh perspectives until the path to the solution becomes clear. I am reminded of the chicken who starved while looking at feed through a wire fence, unaware that the fence extended only a few feet to either side. An extreme example of the power of variation, in this case "ignorant" variation, is given by the role of mutation in the theory of evolution.

One method of varying the problem recommended in Polya's heuristic is to drop part of the condition and see if you can solve the resulting, related problem. This was done by Galileo's mission designers when they were faced with the problem of getting the spacecraft launched to Jupiter after the 1986 explosion of Challenger; the powerful Centaur upper stage was banned for use on the shuttle as part of the overall safety review. The engineers knew that planetary gravity assists were a possible substitute, but, seemingly convenient Venus was unavailable because it was too close to the Sun and Galileo was not thermally prepared for these warmer environs. But they dropped this condition and showed, dynamically, that the use of Venus and Earth for gravity assists would do the trick. The Galileo Project was delighted and carried out the necessary thermal modifications to the spacecraft.

Incidentally, Galileo has made its closest approach to Earth on December 8, receiving the second gravity assist from our planet and is on its way to Jupiter. The navigation to the aim point at Earth was excellent, less than 1 km deviation for the 300 km altitude flyby. Scientifically, valuable data for Earth and Moon (including polar regions) were obtained, and the Instruments were calibrated for their primary use at Jupiter.

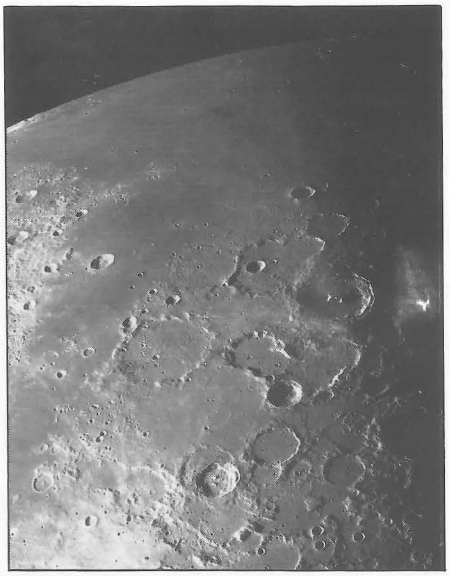
Donna Wolff, who supervises the Mission Planning Group at JPL, recently addressed the question of how to make spacecraft more operable, i.e., more user friendly. She convened a group meeting that worked on the premise of listing attributes that would make a spacecraft less operable. What deep psychological resources can be mobilized, in all of us, when the problem is rotated by 180 degrees!

With this approach the group easily came up with a number of "recommendations." Equip the spacecraft with a "wimpy" propulsion system so that the flight team must spend long hours conducting manoeuvres. Include many appendages in the vehicle's architecture, many deployable, thereby complicating both initialization of the flight system and planning clear lines-of-sight for remote-sensing observations. Insist on many moving parts so that the likelihood of component failure is enhanced, promoting arduous procedural workarounds. Insure the necessity of extensive and exacting planning at all times by building no margins into the power and data subsystems, and, as a bonus, make sure that all of the subsystems affect one another.

The ability to alter our stance with respect to a problem is important but so is the stock of knowledge from which we draw. One of Polya's primary questions is "have you seen it before?" Without experience even the best of associative memories falls short.

I was motivated to write "Prediscovery Evidence of Planetary Rings" (***JBIS***, August 1980) in order to explore the possibilities for discovery inherent in slight or even contradictory bodies of evidence. Answering Polya's question by reflecting on the then-known rings about Jupiter, Saturn and Uranus, I predicted, by analogy, rings about Neptune. (However, whatever small merit might inhere in this act of prescience was erased by my waffling about the case of Pluto, as I note upon rereading the paper.)

Piling up large collections of facts is normally not a productive activity, unless you plan to specialize in being a contestant on game shows. I have observed that those facts and experiences which seem to serve me best, and remain available for long periods of time, are ones that have been attached to centres of personal interest.



This view of the northern polar region of the Moon was obtained by the camera of the Galileo spacecraft as it flew by our satellite in December 1992. The range is 121,000 km. The large lava plain is Mare Imbrium. The north pole of the Moon is toward the darkened region in the cratered area.
NASA/JPL

For example, for reasons of psychology unknown to me, I had been interested since graduate school in representing, in part, trajectories by recording their intersections with spaces of lower dimensionality than the one in which they reside. (Technically, Henri Poincaré's "surface of section" is perhaps the prime example of the technique.) Finally, in 1976 this base of knowledge came to life when it was transformed into a way of graphically representing the scientific consequences of different observational strategies for the Infrared Astronomical Satellite (IRAS), launched in 1983.

The abilities to shift perspective and to bring previous experiences to bear on a problem are the linchpins of technique. However, I believe that there is an even more fundamental attribute of the successful problem solver. As Polya phrases it: "The open secret of real success is to throw your whole personality into your problem."

Isaac Newton (1642-1727) not only provoked the admiration of his contemporaries for his astonishing set of discoveries but also left them wondering how it was possible to accomplish so much. When asked how he discovered the law of gravitation, he responded, "by thinking about it all the time." Using the law of gravitation and his three laws of motion, he was able to explain, among his many successes, numerous features of the Moon's motion. Even the great Newton showed limits to his power of concentration when he complained that the lunar theory made his head ache.

Newton's two remarks - on concentration and one of its affects - were suspended in my mind for a number of years (undoubtedly attached to a Polya-related cluster of facts) before I realized that the second lent credence to the first. What if Newton was telling the exact truth and stating the most important "secret" of his heuristic: hard work without distraction? This, of course, is a variant of Polya's "...throw your whole personality into your problem."

Although one can shrug off this hypothesis by pointing to "acts of brilliance" by prodigies, the method of the effortless solution is only one path to an end. It is the results that count. To counter the example of the inexplicable prodigy, I submit the life and work of the philosopher Immanuel Kant, an admirer of Newton, who, to the best of my knowledge, "ground it out." Like Newton, he changed the way we think about the world.

Even if one accepts the doctrine of concentration as the basic condition of discovery, it is clear that we cannot all excel in all areas; we return to the importance of personal interest, not just in acting as an attractor for the retention of facts, but as a way to multiply our natural powers manyfold.

The French abbé Ernest Dimnet (1866-1954), in his delightful book, *The Art of Thinking* (Simon and Schuster, New York, 1928), is one of many commentators who endorses a blend of concentration, "interior solitude", with following personal bent, "be yourself." The two ideas are conjoined in the following passage from Dimnet. "Genius never plods. When Buffon defines it as a 'long patience' he means not the patience of doggedness, but the perseverance of enjoyment. Who will believe that, during the seventeen years of his quest after his law, Newton did not derive immense pleasure from what we wrongly call his work, but which ought to be called the fascinating occupation of his mind? Genius is well known to be able to devote longer stretches to its work than ordinary talent which needs intervals of relaxation. The reason is that the relaxation of genius lies in the consciousness of doing what it loves to do and would hate to forego."

The art of problem solving, then, is a tapestry of many threads, including: agility, knowledge, and compulsive persistence. Indeed, the effort can make your head ache, but the exhilaration of success is a unique pleasure.

Even if one accepts the doctrine of concentration as the basic condition of discovery, it is clear that we cannot all excel in all areas; we return to the importance of personal interest, not just in acting as an attractor for the retention of facts, but as a way to multiply our natural powers manyfold.

Correspondence

Historical Space Video Recordings

Sir, As this matter still appears to be one of contention (***Spaceflight***, January 1993, p.34), I decided to find out the facts once and, hopefully, for all.

I asked in my second letter an open question as to which 'space footage' we were actually worried about, and I accept that the "television space studio" footage appears just as important as the NASA footage. My original correspondence with Ian Broadbent - which was not through the columns of ***Spaceflight*** - revolved around the idea of the BBC releasing, for home viewing, compilation videos of the Apollo coverage. Consequently I did a certain amount of research, firstly for Ian, secondly for my own interest, into just what was still available in the BBC's Film and Video Library. Hopefully readers will accept that entries in any library under "Space", or even "Apollo", could be fairly large, which is the case, and the 'Space Studios' themselves were not singled out at that time. However as it now appears that it is these Studios themselves that are the main interest, I contacted the Library again to check the entries yet again. However this only confirmed what I had in fact already suspected, that the Space Studios were not actually recorded, with the consequence that it makes any subsequent releases somewhat academic.

To quell the cry of "Why not?" you have to remember that the Apollo missions were late sixties/early seventies and although it may seem strange that television technology lagged behind, say, manned space flight, it did to a certain extent. We were only just in colour in the UK in 1969, (BBC-2 in 1967; BBC-1 and ITV, 1969) and professional video recorders were still on the 2" format and correspondingly large. The Space Studios also went on for some hours each day and would have used up several spools every transmission. Therefore it was decided not to record what was after all a live programme. (This was not that the Space Studios were being victimised, this was common with all live programmes). In addition, and as I said in my first letter, we cannot even resort to a non-broadcast quality of tape (which has been done to reconstruct some episodes of Doctor Who), as this was also before the common use of 'domestic' video; VHS had still to arrive, and Phillips 1500 and 1700 were still hardly plentiful.

Although the main content of the live Space Studios never existed on tape, pre-recorded inserts used throughout the programme were on film and do still exist. Memories of later programmes using clips from these Studios probably relate to these filmed inserts. As I discovered, first time around, it seems that the majority of the 'other' space programmes - Horizon etc - do still exist and so maybe there is a possibility of "reconstructing" the basic feeling of the time of Apollo television coverage? If anything new comes out of this, you will - as they say - be the first to know.

MAT IRVINE
Bucks, UK

Radio Amateur Activity from Space

Sir, Having been a shortwave listener since 1978, I first became interested in listening to Radio Amateur traffic from Space on the 2m amateur VHF-band in November 1985 when Germany had their D1-mission up.

Included on this mission was amateur activity with the callsign DP0SL, on a downlink frequency of 145.575 MHz and modes FM/CW. I happened to hear their CW-beacon only once.

Amateur activity was started back in November 1983 when Owen K. Garriot, callsign W5LFL, was active onboard the STS-9 mission on mode FM. In July 1985 this was followed by Tony England, callsign W0ORE, who was active from onboard the STS-51F mission on modes FM/SSTV.

In December 1988, I heard activity for the first time from Mir on the 2m-band. It was Musa Manarov, callsign U2MIR, who was very active. I managed to hear Musa a total of three times. Less active on this mission was also V. Titov, callsign U1MIR, and V. Polyakov, callsign U3MIR. This activity from Mir started back in March 1988, when Musa asked Ground Control for some copies of the Radio magazine to be sent up and the Psychological Support Group asked the staff of the magazine for some copies. They were delighted about the request and included a letter to Musa asking if the crew where interested in becoming licensed as amateurs. They were, apart from a few problems, Musa said. None of the crew was licensed as a Radio amateur, there was no amateur radio equipment onboard, and they also needed a special antenna. These problems were solved and the cosmonauts became active in November 1988.

A great help in my listening to Mir were three articles in ***Spaceflight*** in October 1987, p.80, March 1988 p.108 and April 1988, p.156, although there was one problem. Here in Denmark, and I suppose in some other countries too, we are not allowed to listen to the frequencies mentioned. Then due to antenna problems I was not able to listen to the amateur 2m VHF-band until shortly before the Juno mission in May 1991.

In the meantime until May 1991 there had been some activity from the Mir space station and also from STS-35 in December 1990, callsign WA4SIR, and from STS-37, callsign KB5AWP. Then from May 1991 until mid August 1992 there was a lot of activity from Mir on the 2m-band, more precisely on 145.550 MHz. The activity has been both from Russian cosmonauts and from foreign guest cosmonauts as follows:

May-91	Helen Sharman, callsign GB1MIR, whom I only heard once on mode FM.
Oct-91	Franz Viehböck, callsign OE0MIR, automatic transmission on mode FM/Packet whom I heard a total of four times. In connection with this mission the Austrian Radio Amateur Association issued a very informative 64-page booklet.
Nov-91 to Mar-92	A. Volkov, callsign U4MIR, and S. Krikalev, callsign U5MIR, were very active on 145.550 MHz and mode FM/Packet which gave many amateurs on the ground their first qso's with a manned Spacecraft.
Mar-92	Klaus D. Flade, callsign DP1MIR, was active from Mir on Mode FM. I heard Flade twice. In connection with this mission German amateurs had set up a Ham-station at DLR, which sent out info about the mission every day on the 80m amateur band, more precisely on 3695 kHz LSB.
Mar-92	Also saw amateur activity from onboard the STS-45 mission. Onboard this mission was a total of four amateurs who used the callsign N5WQC, which I heard a total of nine times on mode FM. Languages used were English, French, Dutch and Norwegian. This is the first time ever that I have heard a Scandinavian language spoken from a manned spacecraft, but Kathy Sullivan does speak very good Norwegian.
Aug-92	The French cosmonaut that was sent up to Mir in late July has been heard on 145.550 MHz in French talking to a French station. Unfortunately my French is not the best, so I did not catch his callsign, although I heard him a total of three times.

On the amateur HF-bands there are some nets and stations to be heard that are connected to amateur activity to and from space:

AMSAT-UK net Mon/Wed	on 3780 kHz +/-	at 1900 local time.
AMSAT-UK net Sunday	on 3780 kHz +/-	at 1015 local time.
AMSAT-EU net Saturday	on 14280 kHz +/-	at 1000 UTC.
AMSAT-In net Sunday	on 14282 kHz +/-	at 1900 UTC.

Goddard Space Flight Center, callsign WA3NAN.
Johnson Space Center, callsign W5RRR.
Jet Propulsion Laboratory, callsign W6VIO.

There might also, in the time ahead, be an amateur club set up sending information about the Mir-mission from NPO Energiya, near Moscow. WA3NAN often sends out information and relays STS-flights on the following HF frequencies: 3860, 7185, 14295 and 21395 kHz.

To hear any of the above mentioned frequencies you must have a radio that is capable of receiving In the SSB-mode.

In connection with the Austro Mir 91-mission, the Austrian Shortwave Service sent out a lot of information in their German language service, which was also about the amateur experiment Aremir.

In the spring of 1993 a German SAFEX D2 will take place onboard a space shuttle. Unfortunately due to its low inclination this mission will not be audible here in Northern Europe. To compensate for this German amateurs will set up a relay station at Tenerife which will send to and from the Shuttle on the 2m amateur band and relay to and from Europe on the 20m/15m amateur bands. In connection with the D2-mission the DLR-clubstation DF0VR will again be active as during the D1 and the Mir-92 mission.

Further reading may be found In ***Spaceflight*** :

1990 February p.70 and June p.186;
1991 February p.46-53, April p.116-117, June p.196-197, July 226-231 and August p.268-269;
1992 May p.146 and 147.

J.K. ANDERSEN
Skagen, Denmark

Space Music and Songs

Sir, Having read Mark Hempsell's December 1992 ***Spaceflight*** article, I look forward to the release of Tasmin Archer's debut album in the USA. I would like to thank Mr Phillips' response to that article, published in the January 1993 ***Spaceflight***, which listed several space songs of which I had not heard. Hopefully, I can now return the favour by adding to the list he offered in his letter.

Mozart's Symphony No 41 was called "Jupiter", while Mahler's Symphony No 1 was called "Titan", although it is questionable whether these can be considered space music.

There are two electronic versions of Holst's "The Planets" - one by Isao Tomita and another by Michael Gleeson. Morton Subotnick's "Return" was commissioned to commemorate the return of Comet Halley to the inner Solar System in 1986. Also in the genre of electronic music, the Voyager missions inspired at least three works:

Wendy Carlos	"Digital Moonscapes"
Ian Tescee	"Io"
Michael Lee Thomas	"Voyager - Grand Tour Suite"

Turning to pop music, we must first of all remember "Fly Me to the Moon", which Frank Sinatra made famous. However, perhaps the first song of the Space Age was "Telstar", an instrumental recorded by the Tornadoes, which was inspired by the launching of the telecommunications satellite of the same name.

I recall a song about an alien called "Purple People Eater", which dates from the late 1950s or early 1960s. Perhaps someone can supply the name of the artist. Other Close Encounters set to music were:

The Byrds	"Mr Spaceman"
Creedence Clearwater Revival	"It Came Out of the Sky"
Jefferson Airplane	"Have You Seen the Saucers?"
Styx	"Come Sail Away"

David Crosby's "Triad" (also recorded by the Jefferson Airplane), with its free love theme and its reference to "water brothers", seems to have been inspired by Robert A. Heinlein's novel *Stranger in a Strange Land*, and as such might qualify as the first Martian love song. The Jefferson Starship's first album, "Blows Against the Empire", an account of the hijacking of the first starship by a throng of hippies, Is reminiscent of the Heinlein novella *Methuselah's Children*.

The Moody Blues wove space themes Into their music in songs such as "Higher and Higher", "Floating" and "The Best Way to Travel". Other space rock songs of the 1970s were:

The Steve Miller Band	"Space Cowboy"
Yes	"Starship Trooper"
Aerosmith	"Spaced"

Mr Davey mentions in his letter, also published in the January 1993 ***Spaceflight***, that John Denver Is on the National Space Society's Board of Governors. Several years ago, Denver tried to get a ride on the Space Shuttle, but In the wake of the Challenger accident, NASA turned him down. He also approached Glavkosmos about a Soyuz mission to Mir, even offering to pay his own way, but they could not agree on a price. Denver later wrote "Flying for Me", a tribute to the Challenger's last crew which also gave voice to his own yearning to go into space.

There is a Grateful Dead song called "Dark Star", not to be confused with the Crosby, Stills and Nash song of the same name. Also, in tradition spanning more than twenty years, the Grateful Dead have segued into dissonant instrumental improvisations midway through the second set of their concerts. Obviously, no two such performances are the same, but among Deadheads these are collectively known as "Space". Several of these improvisations have been collected on the album "Infrared Roses", where they have been given individual names. Lastly, of all the space songs I have heard, my favourite by far is the Grateful Dead's very moving anthem "Standing on the Moon", which commemorates the twentieth anniversary of the Apollo 11 landing.

The discussion of space music in this letter and In the ***Spaceflight*** references cited above has been confined to that produced by Western culture. We should consider that in Russia, where the former Soviet government actively tried to promote a "space culture" for three decades, there are certainly many works of which the Western world is not generally aware. I would enjoy hearing from our Russian members on this subject.

THOMAS GANGALE
California, USA

Songs and Space

Sir, I am writing in response to the Correspondence Column in the January 1993 issue of ***Spaceflight***, in which my letter, concerning the general paucity of songs and music supporting space flight, seemed to be at least partially contradicted by the letters from Messrs Cresdee and Phillips, also published in that issue.

While I am happy to accept the existence of the various titles mentioned by them and, Indeed others (I have a tape by Barbara Dickson, containing a song - 'The Same Sky' - about an astronaut), I feel that your other correspondents have missed the point, which is that most of the works are either purely descriptive - 'Space is a big, strange place' - or metaphorical, using astronautical terms to describe rather more 'down-to-earth' situations (as is the case with Miss Dickson).

A number of songs are actually critical of space travel, usually from a 'Green' or 'New Age' viewpoint.

I believe the point I made was a perfectly valid one - that 'Sleeping Satellite' is one of a very limited number of songs that actually and specifically support the Idea of space exploration.

P.W. DAVEY
Dorset, UK

The Editor welcomes items of correspondence for publication. The right is reserved to shorten material as appropriate.

Russian Space Transportation Possibilities

Sir, I have been reading with great interest the prospects of cooperation between ESA and Russia in developing spaceplanes and space station hardware. It shows the need for a shuttle type spacecraft in the 20-24 t gross weight category or about a quarter of the weight of the US STS or CIS Buran.

If Hermes is to be used for Mir-2 station support as well, then the AR5/MK2 will not have sufficient power to deliver an effective payload to 51.6 degree inclination. The Proton KM launcher could in principle launch the Hermes with its resource module, delivering greater payload to the required inclination. It would give Hermes the unique flexibility of supporting both 28.5 and 51.6 degree inclinations for space station operations.

On the other hand the proposed Maks spaceplane does provide an attractive solution to low cost payload delivery replacing eventually the current SL4, SL6 and Tsyklon launchers. Its unique RD-701 fits in the thrust category of a second stage for the Zenit launcher. The Proton KM's new LH_2/LO_2 escape stage would also fit as a third stage for the Zenit 3 launcher. Together they would boost Zenit's payload/height characteristics considerably.

NPO Molniya seems to have more than one design for the spaceplane [1]. One design puts the cosmonaut cabin behind the payload bay. No main engines would fit in this version.

M.Q. HASSAN
The Middle East

Reference

1. Interavia/Aerospace World Business & Technology, October 1992, p.124.

Soviet Launch Vehicle Classifications

Sir, In my previous letter, published in the August 1992 issue of ***Spaceflight***, I guessed that Chelomei's UR-200 rocket might be used for launching the Polyot manoeuvring spacecraft in 1963-64 and that Korolyev's SS-10 Scrag ICBM was probably used for two first FOBS-related missions in 1966.

My further inquiries have shown that, though the reasoning behind above statements is true, the conclusions turned out to be too far-reaching.

1. The UR-200 was Indeed supposed to launch the Chelomei-made ASATs of which the Polyots were prototypes [1]. But the UR-200 was test-fired with a live first stage only [2] and the Polyots were to be launched by the production-line two-stage R-7 (the SS-6) boosters. Since third stages were in a short supply, the Polyots were launched underfuelled and used their own engines for an orbit insertion [3].
   So, the SL-5 launcher was in fact neither A-m nor the "D-0" UR-200. It did not exist as a separate type and was the same basic A launcher, which already bears two DoD designations - the SL-1 and the SL-2!
2. The Scrag (its equivalence with the SS-10 was assumed from Congressional Reports) was indeed designed as a FOBS weapon and its genuine name was the GR-1 standing for "global rocket". However, it was never launched and its designers ironically nicknamed the GR-1 "an intercontinental missile Moscow to Leningrad" [4].

Thus, the "E" class of the Sheldon system had to emerge, but failed to do so.

MAXIM V. TARASENKO
Centre for Arms Control,
Energy and Environmental Studies,
Moscow Institute of Physics and Technology

References

1. Leonard S. Legezo, "The Activities in the USSR for the Creation of an Antisatellite System", A presentation at the ISY Conference, Moscow, March 30, 1992.
2. Igor B. Afanasyev, Private communication.
3. Vladimir A. Polyachenko, "On the activities of the OKB-52/TsKBM under the Kosmos programme", A presentation at the ISY Conference, Moscow, March 30, 1992.
4. Igor B. Afanasyev, "Aviatsia i Kosmonavtika", No.8, 1992, p.34.

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.
It may occasionally happen that, for reasons outside its control, the Society has to change the dates or topics of meetings. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always recheck the scheduled meetings in the latest issue.

3 March 1993 — 7 pm - 8.30 pm

Armchair Interstellar Exploration

A.T. Lawton

Although he dreams and plans, it is very unlikely that many men will undertake manned interstellar flight. For those who will never go to the stars - the stars must come to him.

Developments in technology e.g. interferometry, large apertures, new types of high resolution detectors and high fidelity data links will enable this to happen.

As of now they allow us to see solar cycles on other Sun-like stars, detect planetary dust clouds around them and deduce the possible presence of Jupiter like planets.

These techniques can be extended with precision spectrometry to form a catalogue of stars with planetary systems closely resembling our own Solar System.

This is Armchair Interstellar Exploration whereby if we do go, or send a one way robot as proxy, we will have maximum chance of success in locating other life forms.

17 March 1993 — 7 pm - 8.30 pm

Mission Control and Control Centre Operations

D.E.B. Wilkins

The lecture will discuss spacecraft opertions in general, the technology involved and the practice of operations since the early days of space flight.

The lecture will not dwell on the historical aspects of spacecraft control though references will be made to the significant advances achieved in those early years, 1957 - 1969.

The lecture will be presented in three parts: Past, Present and Future, and will be based on the experience and activities of the speaker in the fields of Spacecraft Control and Systems Engineering.

The early NASA Manned Mission control methods will be briefly discussed and the ESA experience in scientific and applications missions described in some detail to expand discussion on Mission Control.

7 April 1993 — 7 pm - 8.30 pm

Cassini

Mr C. Cochrane

Cassini is a project planned by ESA and NASA for a spacecraft to survey the planet Saturn and its environs. During the journey to Saturn, fly-bys and investigations will by made of asteroids and Jupiter. After arrival at Saturn the spacecraft will orbit the planet for a further four years, using remote sensing to examine its satellites, rings and the planet itself. A sophisticated probe will be released in the first orbit to land on the mysterious moon Titan, to explore its atmosphere and surface.

The presentation will describe the scientific objectives of the mission, its trajectories and explain the engineering problems of the Titan Atmosphere Probe, concluding with a review the feasibility of the proposed solutions and present the innovative features of this fascinating mission.

5 May 1993 — 7 pm - 8.30 pm

Results from ERS-1

Dr G.E. Keyte
DRA Farnborough

The European Space Agency's ERS-1 satellite was one of the most complex remote sensing satellites ever launched. Despite its complexity, it has functioned almost perfectly since launch in 1991 and has enabled a wide range of research and application projects to be undertaken.

This paper briefly describes the main characteristics of the ERS-1 instruments and gives an account of their 'history' since launch. Some of the main results obtained from each of its instruments are reviewed, covering both the two microwave instruments (the Active Microwave Instrument and the Altimeter) as well as the instrument provided by the UK, the infra-red radiometer (ATSR). It will conclude by reviewing the future development of microwave remote sensing satellites after ERS-1.

14 August 1993

48th Annual General Meeting

The 48th Annual General Meeting of the Society will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, on Saturday, August 14, 1993 at 12 noon. Details of the Agenda will be published in due course.

Admission is by ticket, available to Corporate Members (i.e. Fellows of the Society) only, who should apply in good time enclosing a stamped addressed envelope.

Council nomination forms are obtainable from the Executive Secretary. These must be completed and returned not later than 12 noon on May 22, 1993. If the number of nominations exceeds the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all Corporate Members.

SYMPOSIA & CONFERENCES

24 March 1993 — 10 am - 4.30 pm

European Rocketry in the 1930's

As part of the Society's Anniversary Year the History Working Group are holding a Symposium on European Rocketry in the 30's. Contributions have been invited from Germany, France, Russia and the UK. The 30's is seen as a particularly interesting decade in that much theoretical and practical work was undertaken that laid solid foundations for later projects.

Whilst much publicity has surrounded the experimental and theoretical work carried out in Germany an enormous amount was also carried out elsewhere, particularly in Russia. Much of this story has yet to be told.
Advance Registration is necessary.
Registration: Forms are available from the Executive Secretary. Please enclose a sae.

19 May 1993 — 10 am - 5.15 pm

Electric Propulsion of Spacecraft

Dr D.G. Fearn
DRA Farnborough

A one-day technical symposium under the chairmanship of Dr D.G. Fearn, Defence Research Agency, Farnborough, Hants.

Papers will be presented on the status of different ion thrusters and propulsion systems under development as well as other topics relevant to electric propulsion.
Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Advance Registration is necessary.
Registration: Forms are available from the Executive Secretary. Please enclose a sae.

12 June 1993 — 10 am - 4.30 pm

Soviet Astronautics

The symposium is in its 13th year as an event which reviews the space programme of the former Soviet Union. The programme for 1993 will include talks on the following topics: The Biosputnik programme up to 1993; USA-Russian Manned Cooperation 1992-1995: update on the Manned Operations on Mir; Obscure Unmanned Soviet Satellite Missions, and others still to be decided. A Film will be shown including clips never seen before in the UK. There will be opportunities to ask questions of some of the leading experts on the Soviet Space Programme in the West.
Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Advance Registration is necessary.
Registration: Forms are available from the Executive Secretary. Please enclose a sae.

VISITS

31st March 1993

London Teleport

(Isle of Dogs)

A one-day visit with briefings and tour open to a limited number of members interested in the EUTELSAT and similar programmes.

Pre-registration is necessary. Details of programme and Registration forms are available from HQ on request. (See p.78).

21 May 1993

Royal Aircraft Establishment/Defence Research Agency

(Farnborough, Hants)

A one-day visit with briefing and tour open to a limited number of members interested in remote sensing, advanced propulsion systems etc.

Pre-registration is necessary. Details of Programme and Registration forms are available from HQ on request. (See p.78).

LIBRARY

The Society Library Is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. Membership cards must be produced.

2 WAYNE

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The International Magazine of Space and Astronautics

Space Year Highlights

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SETI

Giotto

Space Shuttle

ISSN 0038-6340

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Shuttle Mission Report: STS-47

Stonehenge from Space *By Dr M.J.F. Fowler*

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All videos are extracted from original footage.

NEW

Apollo 8: Go For TLI

This Saturn V flight was man's first journey around the Moon and forerunner of the Apollo lunar-landing flights. The three-man crew (Borman, Lovell and Anders) set course for the Moon, passed behind it and transferred to a lunar orbit, circling the Moon ten times in 20 hours. Their many still photographs and much cine film helped to decide on landing sites for later missions. The final TV transmission took place while 97,000 miles from Earth. *22 mins*

Apollo 9: Three to Make Ready

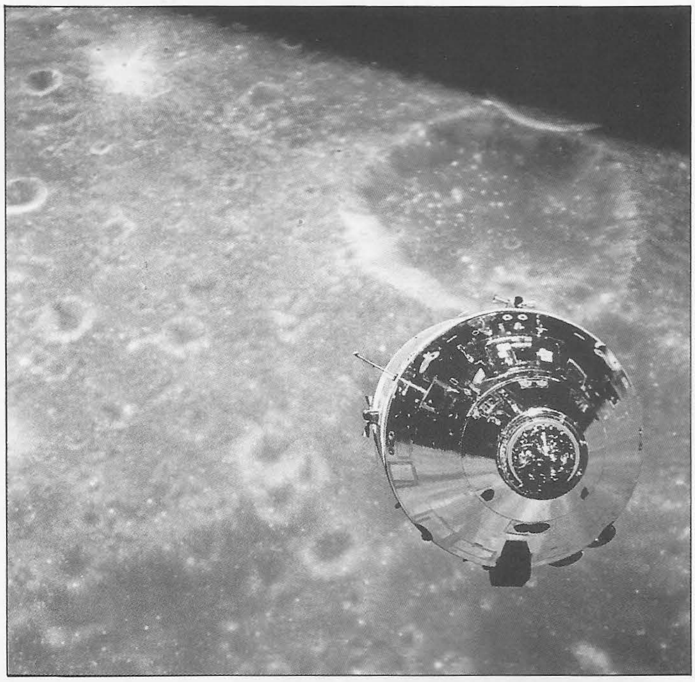
Building on the successful flight of Apollo 8, a lunar module was tested in space, as was the life support system of the space suit. Two of the three-man crew (McDivitt, Scott and Schweickart), transferred to the Lunar Module, moved 100 miles away from the Command Module and then returned to rendezvous with it. The two men then transferred back to the Command Module and the Lunar Module was jettisoned. *17 mins*

STS-49 Mission Highlights

The details of this flight by the Shuttle Endeavour, 7-16 May, 1992, are well covered, e.g. the preliminaries of suiting-up, the White Room, entry to orbiter, removal of gantry, count-down, engines start, lift-off, and detailed operations during the flight. A principal aim was to retrieve the Intelsat VI satellite which had previously failed to reach synchronous orbit. Though more difficult than expected, it was achieved and sent on its way. A second aim was to practice basic space station assembly work by Extra-Vehicular Activity (EVA). This was also very successful. The video concludes with an interesting press interview with the crew. *1hr 50 mins*

Apollo 10: To Sort out the Unknowns

Lift-off to a trans-lunar orbit by Stafford, Young and Cernon, with views of Earth and system checks *en route*. There was loss of communications signal while passing behind the Moon as the craft transferred to lunar orbit. Signal acquisition returned when the spacecraft reappeared, with TV pictures showing the Lunar Excursion Module (LEM) undocked from the Command Module and descending to within 50,000 feet of the lunar surface. Direct communications between Control and LEM failed so access was made *via* the CM. LEM subsequently rendezvoused with the CM, the crew transferred again and LEM was jettisoned. *26 mins*



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Spaceflight

The International Magazine of Space and Astronautics

Published By The British Interplanetary Society

Vol. 35 No. 4 **APRIL 1993**

Front Cover: Return to Mars. One of the highlights of the International Space Year was the launch of the Mars Observer spacecraft at the Kennedy Space Center on 25 September 1992. The spacecraft is pictured after separation from its Transfer Orbit Stage which correctly positions it and sends it on its way to Mars where it is due to arrive in August 1993. *Orbital Sciences Corporation, Vienna, Virginia, USA*

Space Year Highlights

The 500th anniversary of Columbus' discovery of America was also designated the International Space Year. The spotlight of publicity, it was hoped, would fall on the exploration of space - the modern-day 'New World' of discovery - and the benefits that this could bring to the nations of the world. In the event, it was world-wide recession and budgetry pressures that grabbed the headlines.

Nevertheless, 1992 saw many notable space events. A selection of these are presented in this issue:

Journey to

On July 10 1992, the European Space Agency's (ESA) Giotto spacecraft passed within 200 kilometres of the nucleus of the short-period Comet Grigg-Skjellerup. Somehow, Giotto's flyby of Comet Grigg-Skjellerup did not quite generate the same news impact as its previous encounter with Comet Halley. The British-built detectors on Giotto's front meteoroid bumper shield measured a grand total of 3 dust impacts at Grigg-Skjellerup compared with about 4,000 during the Halley flyby in March 1986. These are telling statistics that highlight that Halley and Grigg-Skjellerup are very different types of comets, with highly individual patterns of behaviour. This is extremely good news for cometary scientists who, after years of patient study using ground-based observatories, now have access to comparable, in-situ measurements of two highly contrasting cometary bodies.

BY DARREN L. BURNHAM
Oxford, UK

The main difference between Halley and Grigg-Skjellerup is the rate at which the comets produce gas and dust. At the peak of its activity Halley produces more than 30 tonnes of material every second - enough to fill a large truck. By contrast, Grigg-Skjellerup produces just less than 1% of this amount of material - barely enough to pack a small family car. Yet, for all of this, Grigg-Skjellerup still managed to possess quite a sting in its tail.

"An Event, We Have A Dust Impact"

A simple numerical count of the number of dust impacts does not by itself tell the full story, particularly as there were rather more subtle differences in the type of dust that Giotto encountered at each of the comets. At Halley, Giotto measured a well balanced mix of dust particles, ranging from minute particles smaller than smoke up to much larger pieces the size of a grain of rice. However, similar findings were not immediately apparent from the first results of the Grigg-Skjellerup encounter.

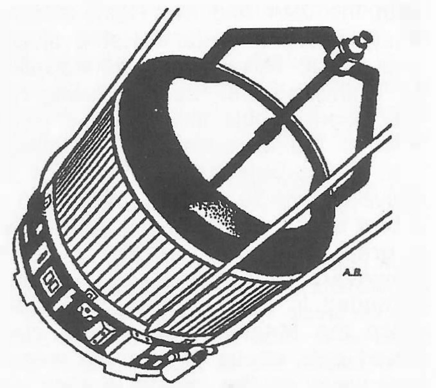
Analysis of the data returned by the Optical Probe Experiment (OPE), a photopolarimeter which can measure concentrations of dust and gas, reveals that Giotto entered the dust coma some 17,000 km from the nucleus, while still 20 minutes away from the point of closest approach. Theoretically, the spacecraft had entered the zone where the highest concentration of dust activity could be expected, and conditions could only worsen from this point onwards. In reality, Grigg-Skjellerup presented two quite contrasting pieces of evidence. As the density of very fine particles - as measured by the OPE - steadily increased, there was no immediate sign of the larger particles which could be registered by Giotto's Dust Impact Detection System (DID). Professor Tony McDonnell and his team of scientists from the University of Kent, Canterbury, who had supplied the DID experiment, had predicted that most impacts would be concentrated within a 20 minute period spanning either side of the closest approach. Initially, the scientists were quite relieved that this worst case scenario was not confirmed, for the greater the presence of dust particles, the greater the risk of damage to the spacecraft. However, as the final seconds of the countdown to closest approach ticked by, the absence of larger dust particles became ever more inexplicable.

Just when it was beginning to look as if Giotto might escape without being hit by any dust, Tony McDonnell was heard to exclaim: "An event, we have a dust impact!" - at long last the first sizable dust grain had registered its presence on the front bumper shield. At first it was thought that Giotto had been hit by two separate particles almost instantaneously, but later analysis showed that the first particle had been large enough (approximately 100 micrograms) to trigger two of the DID sensors. "BigMac" (as the first impact has since been named) was followed in quick succession by the detection of another, much smaller impact estimated to weigh about 2 micrograms. The third and final dust impact to be registered by the DID sensors occurred about 40 seconds after the first and weighed approximately 20 micrograms.

In the midst of all this activity - and unbeknown to the scientists of the DID team - an "extremely large particle" hit Giotto in an unprotected region at the rear of the spacecraft. Weighing in at an estimated 50 milligrams this particle was large - even by the treacherous standards of the Halley flyby - and its arrival was all the more surprising in the context of the rather low levels of dust activity observed in Grigg-Skjellerup's inner coma. "Whopper", as the particle is now affectionately known, left a measurable effect on the spacecraft. Almost immediately after the impact, the staff manning the consoles at the European Space Operations Control Centre (ESOC) in Germany began to observe that Giotto's spin rate had increased by 0.003 rpm and that the spacecraft's axis of spin was nutating at an inclination of nearly one tenth of a degree. A drag-induced deceleration associated with this impact was also measured by the Radio Science team.

Fortunately for all concerned, Giotto weathered the storm, and there was no repeat of the breakdown in communications which occurred during the most critical point of the Halley flyby. Although a little shaken by Whopper's impact, Giotto continued to transmit high quality data for the entire duration of the outward journey.

Grigg-Skjellerup



Closest Approach

The point of closest approach actually occurred at 15:18 GMT, but since the encounter took place at a geocentric distance of almost 214 million km, it was not until 15:30 GMT that the radio signals relaying this good news reached Earth.

As it sped past the nucleus, Giotto broke its own record for the closest cometary flyby yet achieved, with its 200 km flyby of Grigg-Skjellerup bettering the 600 km flyby which it had previously achieved at Halley. The 200 km figure is only a rough estimate and may err by as much as +/- 100 km. The estimate was derived using brightness data from the Optical Probe Experiment, and is supported by the peak magnetic field readings of the Magnetometer team. Although this value is only approximate, it is still considerably better than the minimum flyby distance of 1000 km which flight controllers had been hoping for following the final course correction on July 8. To achieve such a close flyby Giotto was aimed directly for the nucleus, but since the comet's position could not be precisely measured, the chance of a direct hit was very small indeed, perhaps no more than one in several tens of thousands.

Giotto's course took it right through the tail-forming region on the "night" side of the nucleus. Since Giotto was not equipped with any data recording units it was absolutely essential that its main High Gain Antenna remain pointed towards Earth, in order to maintain communications throughout the encounter. Unfortunately, this resulted in a less than optimal orientation for the encounter, in which the spacecraft swept through the comet on its broadside. As a result, the efficiency of some of the surviving instruments was reduced, and the low grazing angle may explain why the front dust shield registered such a surprisingly small number of impacts.

Another side-effect of the awkward encounter geometry was the fact that Giotto's solar cells had to bear the full brunt of the dust impacts, giving rise to fears that their sensitive circuitry could be damaged. This was all the more worrying as Giotto was already burdened by the loss of its chemical batteries. Even without this handicap, electrical power was a scarce resource which needed to be carefully rationed. At the time of the Grigg-Skjellerup encounter Giotto was over 16 million km further from the Sun than its designers ever intended, and the output of its solar arrays was down by some 20%, leaving barely enough power to operate all of the surviving instruments at the same time. In order to provide greater margins for the safe operation of the payload during the encounter, ESOC therefore elected to conserve power by switching off the uplink from Earth.

Seven of the original suite of ten instruments were powered up and working during the encounter with Grigg-Skjellerup. Of these, the Ion Mass Spectrometer suffered somewhat from the lower encounter velocity (a leisurely 14 km/sec when compared to the 68 km/sec of the Halley encounter). The instrument recorded a good deal of data, but the process of drawing reliable conclusions from these readings is taking some time.

Cometary Processes

To place some of Giotto's findings in their proper context, it is perhaps appropriate to consider some features of the anatomy of a typical comet and the way these behave with respect to the environment of interplanetary space. The nucleus of a comet is no more than an agglomeration of ice and dust particles, loosely held together to form a solid body. As a cometary nucleus approaches perihelion it is heated by the Sun's radiation, and begins spewing large volumes of dust and gas to form a local atmosphere, the coma, around the nucleus.

Not surprisingly, all of this cometary activity has measurable effects on the solar wind - a continuous flow of protons and electrons which stream away from the Sun at supersonic velocities. Due to the Sun's 27-day rotation period, the solar wind spirals radially outwards, rather like the motion of droplets of water moving away from the centre of a garden sprinkler. The solar wind carries with it a very weak interplanetary magnetic field, whose strength is a mere 1/5000th of that at the Earth's surface.

The first signs of the comet/solar wind interaction can usually be found several million kilometres away from the nucleus. The neutral gas (consisting mainly of water molecules) flowing out from the comet's coma is ionised by solar ultra-violet radiation and begins to interact with the electric and magnetic fields of the solar wind. The newly-created charged particles are accelerated, stealing energy from the solar wind with the net effect that the solar wind is slowed down. The effects of this process are hardly noticeable at first, but become gradually more apparent as the distance to the nucleus diminishes. Eventually the solar wind is slowed to the point where it forms a bow shock directly in front of the comet.

A second boundary, called the contact surface, lies even closer to the nucleus. Eventually the density of cometary ions becomes so high that the highly conducting plasma excludes the magnetic field of the solar wind, forming a magnetic cavity around the nucleus. The magnetic field drapes around the comet, forming a plasma tail in its wake. The magnetic cavity itself takes the form of a teardrop and is filled with material entirely of cometary origin. Because of the richness of the gas surrounding the nucleus, chemical reactions can occur and this leads to the formation of molecular compounds. Data from Giotto's Halley flyby revealed that the largest proportion of these gases are quite familiar: water vapour (80%), carbon monoxide (10%) and carbon dioxide (3-4%). Giotto also found traces of several more exotic compounds such as polymerised formaldehyde. Most of these compounds do not survive very long as by the time they reach the outer coma they have either been broken down into their base elements or have formed much simpler compounds.

The Grigg-Skjellerup Encounter

In the Grigg-Skjellerup flyby, the first detection of cometary ions was made while the spacecraft was still nearly half a million km from the nucleus. The ions were picked up by Britain's other major contribution to Giotto's payload, the Johnstone Plasma Analyser (JPA) - which had been provided by a team from University College London, led by Professor Alan Johnstone.

The detection of cometary ions came much earlier than had been expected. An explanation for this may be found in the fact that the comet brightened in the days immediately leading up to the encounter, while conversely, the solar wind was unusually quiet. As luck would have it, solar wind background conditions were very similar to those measured at the time of the Halley encounter, making it that much easier for scientists to make direct comparisons between the behaviour of the two comets.

Later on, at a distance of 20,000 km

both the JPA and the Rème Plasma Analyser found evidence for a distinct bow shock. This finding was surprising for it showed that the outgassing rate was about double the expected value. Prior to the encounter it was thought that Grigg-Skjellerup might not be active enough to allow the formation of a bow shock, and certainly not at such a great distance from the nucleus. However, these findings are still shrouded in a great deal of mystery, since the Magnetometer team diagnosed only traces of a much weaker bow wave on the inward journey. On the outward leg, all three instruments were in agreement as the unambiguous signature of a bow shock was distinguished at a distance of 25,000 km from the nucleus.

The Magnetometer readings prove that while the spacecraft passed very close to the nucleus, it did not cross the contact field and magnetic cavity. This again provides an indication of the respective sizes of Grigg-Skjellerup and Halley, for although Giotto passed much further from Halley's nucleus, it still plunged right through the magnetic cavity. In Halley's case the magnetic cavity was found to lie some 4,700 km from the nucleus, while it has been estimated that Grigg-Skjellerup's magnetic cavity extends no further than 60-90 km from the nucleus.

Other Magnetometer findings which will be the subject of much analysis in the years to come were the wave phenomena discovered in Grigg-Skjellerup's inner coma. The waves, which are produced by the ionisation of cometary material, were of a complexity which has never been observed in a natural plasma before. Signs of these "fantastically large waves" with wavelengths of several thousands of kilometres were also detected by the Rème Plasma Analyser. There was also an excellent correlation between the Magnetometer readings and the findings of Ireland's Energetic Particle Analyser.

The results of Giotto's encounter with Grigg-Skjellerup have surpassed all expectations, and once again Giotto has made an outstanding contribution to the advancement of cometary science. The jubilant mood of the experimenters was summed up by Professor Alan Johnstone, who was asked during the encounter whether all the new data would make it any easier to describe the nature of a "typical" comet. His reply hinted of the enormous task facing the cometary scientists in the months ahead: "No, but we're not looking for an easy life that way. It's certainly going to be very interesting to analyse the data, and I think we'll be able to do some excellent work on it".

On The Comeback Trail Again?

While the scientists continue the task of sifting through and interpreting all the data, what of the star player in all this, the spacecraft itself?

At the current time Giotto is dormant again, having been placed in a state of hibernation on 23 July 1992.

A third cometary flyby has been mooted, but the permutations for such are somewhat restricted by the fact that Giotto's propellant tanks have only 4 kg (+/- 3 kg) of hydrazine left for mid-course corrections. Bearing in mind that a considerably larger amount of fuel was needed to set up the flyby of Grigg-Skjellerup, the identification of yet another suitable target will either be an extremely fortuitous stroke of luck, or a text-book example of the creative use of celestial mechanics.

As tempting as the idea of a third cometary encounter may be, a number of scientists associated with the mission feel that now is an appropriate time to lay Giotto to rest once and for all, and focus instead on developing the next generation of cometary explorers [see p.115]. Even assuming a feasible trajectory can be found to reach another target, the case for another extension of Giotto's mission is not entirely convincing. Putting aside the damage sustained during the Halley encounter, the spacecraft is now beginning to show signs of its age. Giotto was built in the early 1980s using the technology of the late 1970s. By the time 1999 arrives the spacecraft will have been in space for 14 years, and will not be far short of becoming a museum piece. Whilst such long mission durations are not without precedent in the field of deep space exploration (à la Voyager 2) the disparity between the equipment in use on the ground, and that in use on board Giotto can only widen, adding tremendously to the risk and complexity of another extended mission.

Whatever the outcome of these deliberations, engineers believe that Giotto may have already pioneered, a new, lower cost approach to the exploration of deep space. Traditionally, spacecraft travelling through the depths of space remain under constant surveillance from ground control on Earth, with regular communications being scheduled at least once a week if not more frequently. This, however, requires a large commitment - both in terms of manpower and equipment - which is expensive to maintain over long periods of time. The knock-on effect of this is what drives up the operating costs of each mission and in some cases makes them prohibitively expensive to undertake. The Giotto mission has, however, shown another way around this problem, for by using extended periods of hibernation, the encounter with Grigg-Skjellerup has been successfully accomplished at a bargain basement price of £4½ million. While the hibernation approach may not be applicable to many deep space missions which make many important measurements en-route to their destinations, for those such as the Giotto mission with well defined objectives concentrated in short bursts of activity, this could produce considerable savings in costs over the long-term.

In the short-term, Giotto's successful flyby provided a much needed shot in the arm for a space agency which - in common with most others - has not enjoyed the best of times these past few years, and reminded the Science Ministers of ESA's member nations that European scientists can make a significant contribution to the exploration of space when they are given the opportunity.

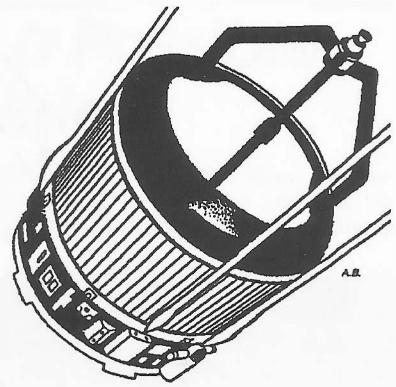
A Tale of Two Comets: Key Parameters of the Halley and Grigg-Skjellerup Flybys Compared

	Halley	*Grigg-Skjellerup*
Encounter date	14 March 1986	10 July 1992
Encounter time	0:03 GMT	15:18 GMT
Closest approach	596 km (+/- 2 km)	200 km (+/- 100 km)
Encounter velocity	68 km/sec	14 km/sec
Distance from Sun	134.6 million km	151.1 million km
Distance from Earth	143.6 million km	213.9 million km
Size of nucleus	15 x 8 km	2 km (estimated)
First detection of hydrogen pick-up ions	7.5 million km	440,000 km
Bow shock	1.1 million km	20,000 km (inward pass) 25,000 (outward pass)
Ionopause	4,700 km (inward pass) 3,900 km (outward pass)	60-90 km (estimated)
Maximum magnetic field intensity	65 nT	87 nT
Gas production rate	6.9×10^{29} molecules/sec	6×10^{27} molecules/sec

Acknowledgements

The author gratefully acknowledges the assistance of Dr Neil McBride (University of Kent), Professor Alan Johnstone (University College London) and Professor Susan McKenna-Lawlor (Space Technology (Ireland) Ltd).

Health Check on Giotto



British Aerospace Space Systems, Prime Contractor for the European Space Agency's Giotto spacecraft, have recently completed a study to assess its operational capability following the encounter with Comet Grigg-Skjellerup on 10 July 1992. The assessment, based on analysis of housekeeping telemetry files available at the European space Agency Operations Centre (ESOC), Darmstadt, Germany concludes that the spacecraft remains in remarkably good health, but that there is little prospect of a further follow-on mission.

BY RICHARD FLOWER
British Aerospace Space Systems, Bristol

Background

The Giotto spacecraft was launched in July 1985 on a scientific misison to Halley's Comet. The cometary encounter was successfully accomplished on 13/14 March 1986 with a closest approach of approximately 600 km. Despite sustaining some damage from high velocity dust particle impacts, the spacecraft survived the encounter in generally good health. To keep options for a further mission, Giotto was placed into a suitable hibernation orbit in April 1986, with non-essential units switched off and no ground contact.

Following successful spacecraft reactivation and checkout in 1990, the decision was made to embark on a follow-on mission to a second selected target (Comet Grigg-Skjellerup). After performing a gravity assisted Earth flyby (the first ever) in July 1990, Giotto was returned to its hibernation state. A second reactivation in May 1992 confirmed the continued health of the spacecraft and the Grigg-Skjellerup encounter was successfully accomplished on 10 July 1992 with a closest approach of approximately 200 km and no discernable damage to the spacecraft.

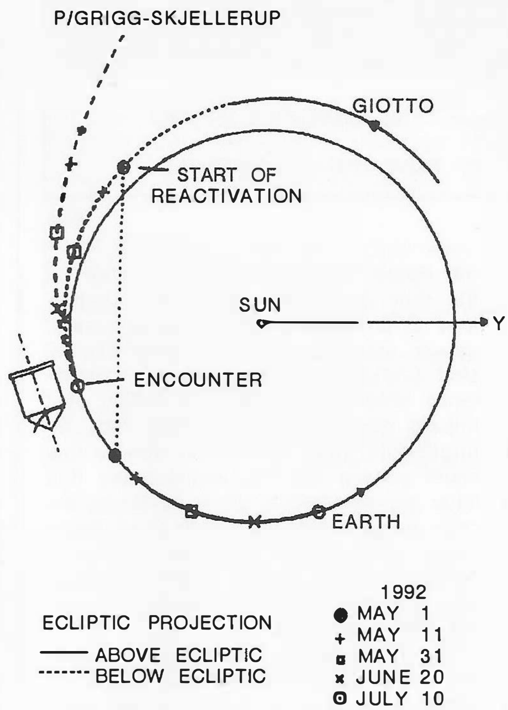
To retain the possibility of a further follow-on mission, Giotto was placed in a trajectory with a July 1999 Earth flyby and currently remains (since July 1992) in its third period of hibernation.

Health Status Summary

Giotto remained in good health throughout Grigg-Skjellerup operations, with few additional anomalies or failures evident since the previous contact in July 1990. The total mission duration now exceeds 7 years, during which time the spacecraft has survived two cometary encounters (being subjected to a severe dust particle bombardment by Halley), two prolonged periods of hibernation two reactivations, a gravity-assisted Earth flyby and hot and cold thermal conditions considerably outside design limits. During the course of the extended mission, several operational modes and scenarios not previously envisaged have been successfully demonstrated.

The Giotto story is one of remarkable achievement, bearing in mind that the spacecraft was originally designed specifically for a 9 month "suicide" mission to Halley's comet with no consideration of a potential follow-on capability.

The Grigg-Skjellerup mission was completely successful. This was in spite of Giotto being particularly vulnerable to failures resulting from its extended lifetime, significantly reduced on-board redundancy and autonomy, non-optimum encounter geometry, large communications distances (1.43 AU at encounter) and very stringent power constraints.



The Orbits of Giotto, Earth and P/Grigg-Skjellerup *BAe*

The encounter geometry, dictated by the need to maintain a high gain antenna (HGA) Earth link, meant that minimal protection was offered by the dual shield dust protection system, putting the spacecraft at risk to dust impacts on its main body. However, the combination of a much slower relative spacecraft/comet velocity (14 km/s versus 68 km/s for Halley) and a benign rather than active comet meant that no observable damage occurred.

Giotto still retains the capability of performing all functions necessary for routine operations. These include stable and accurate Earth-pointing of the despun HGA, commanding and execution of attitude and orbit control manoeuvres, provision of Sun and star sensor data for accurate attitude determination, and housekeeping and high rate scientific data communications at S and X band. The constituent subsystems have been checked out and are reported as follows.

Structure

Structural integrity is maintained with no evidence during either encounter of dust particles piercing the outer structure and entering the spacecraft main body. Significant damage was incurred to the dust shields and external units (including the Halley Multicolour Camera baffle) during the Halley encounter, resulting in a principal axis tilt of approximately 0.2 degree and giving the rotating spacecraft a "wobble". This misalignment actually aided operations during both reactivations by allowing spin rate estimation via Fourier analysis of the residual doppler signal.

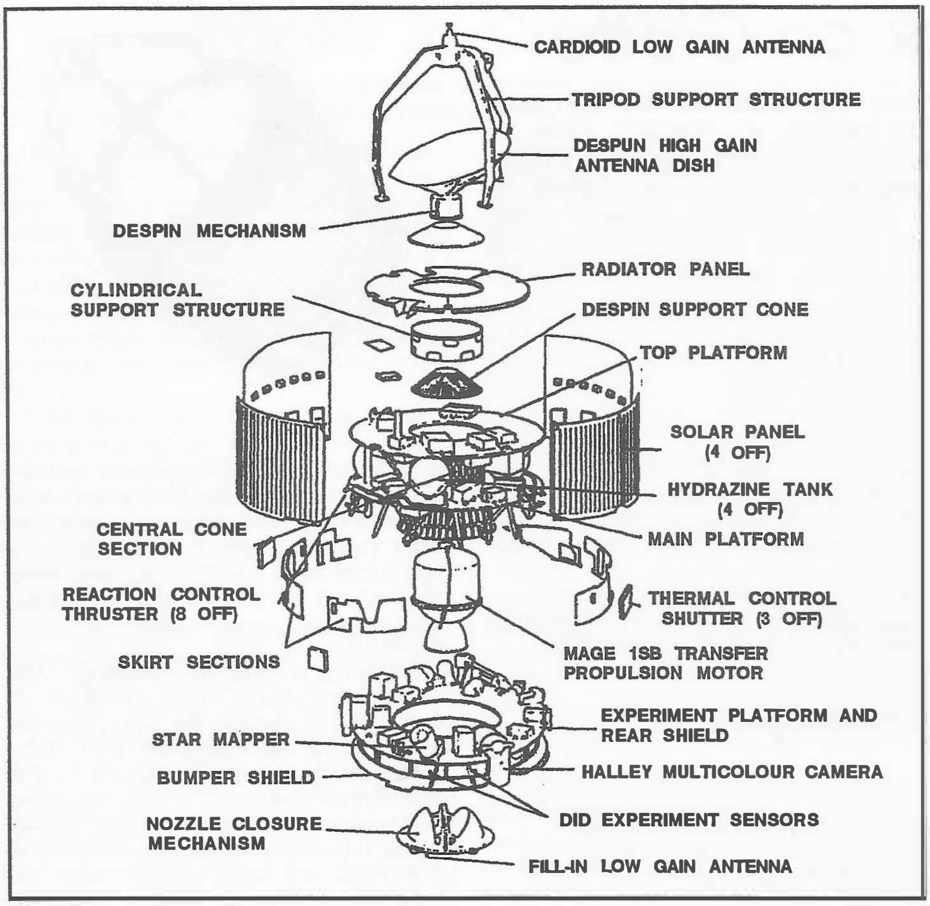
Antenna Despin

The rotating spacecraft (spin rate 15 rpm) maintains a high data rate Earth link by means of the despun HGA, using a Despin Mechanism controlled by redundant Despin Control Electronics (DCE) units and powered by redundant Service Converters.

Serv Conv 2 failed during the first (1986-90) hibernation, probably due to excessively high temperatures. The absence of cross-strapping between the main and redundant units means that DCE 2 can no longer be used, leaving DCE 1 and Serv Conv 1 as mission single point failures. However, these units continue to function nominally and the mechanism has completed a maximum of 41.7 million revs. In order to minimise failures rates, the despin was switched off for both the second and current hibernations.

Antennas

In addition to the HGA, Giotto has two omnidirectional low gain antennas (LGAs). The HGA and Cardioid (LGA 1) antennas, both located at the top of the spacecraft, retain nominal performance. However, the Fill-in (LGA 2) antenna has not been operated since the Halley encounter, its vulnerable location on the outer dust (bumper) shield leading to a high probability of significant dust impact damage. Satellite attitudes with only LGA-2 Earth-pointing must therefore be avoided at all times.



Giotto configuration. *BAe*

Solar Array

The solar array output at Grigg-Skjellerup encounter was 144 W, approximately 6% lower than predictions. This degradation, together with minimal battery capacity and large Sun distances (1.01 AU at encounter) demanded careful power budgetting throughout the extended mission.

The spacecraft encounter geometry left the body-mounted array particularly vulnerable to dust impacts. However, no significant power reduction was observed and there is no evidence of damage to any of the 68 array strings.

Power Supply

The four silver cadmium batteries were found to be fully discharged during the 1990 checkout activities, consistent with observed degradation during the Halley mission and indicating a high probability that they had exceeded their useful lifetime. The decision to proceed with the extended mission at the time was made on the basis of solar array power alone.

However, the critical power situation prior to Grigg-Skjellerup encounter led to initiation of a series of battery tests. It was established that battery 1 was not usable, but the remaining three retained 5-10% of their original capacity - sufficient to provide a buffer against possible switching transient problems. These three batteries were enabled accordingly for encounter, although in the event they were not required.

Thermal and power requirements of previous mission phases necessitated the dumping of excess power via External Power Dumpers (EPDs) located on the rear dust shield. However, anomalous EPD status readings, array current sensor readings and high Power Control Unit (PCU) temperatures were consistently observed, indicative of Halley dust impact damage. Effects were reduced throughout 1992 operations due to low shunt powers and low temperatures (the latter representing a driver to dump excess power internally rather than externally), although the need for margins to compensate for current sensor inaccuracies remains and contributed to the critical power situation.

No power supply distribution anomalies were observed, with the capability retained to provide power to all commanded units. Main bus regulation was nominal with the voltage remaining steady at 27.89 V.

Data Handling

During the 1990 checkout activities, a Central Terminal Unit Processor (CTU Proc 2) failure was observed, probably caused by prolonged exposure to excessively high temperatures. This prevents the unit from being used for telemetry generation, although other functions remain nominal (the unit is enabled for the current hibernation in order to minimise wear and tear of prime units). All functions can be performed by CTU Proc 1, but there is no longer any CTU redundancy when a telemetry downlink is required.

With the exception of the above, all data handling units remain functional and fully redundant with an internal subsystem health monitoring capability retained.

Giotto has a suite of Application Programs (APs) to autonomously monitor critical parameters and instigate suitable reconfigurations as necessary, although their use is now drastically limited by the Serv Conv 2 and LGA 2 failures, star mapper damage and power budget limitations. However, their absence is not mission-critical, and no APs were scheduled throughout the Grigg-Skjellerup mission.

Telemetry, Tracking & Telecommand (TT&C)

Once a stable two-way HGA link was established after reactivation, downlink data quality was consistently good at both S Band and X Band, with nominal operation of both receivers (RX 1 and 2), both S band transmitters (TX 1 and 2) and both X band Travelling Wave Tube Amplifiers (TWTA 1 and 2) demonstrated.

The assumed LGA 2 failure means that RX 2 (connected to LGA 1) represents a mission single point failure, as successful reactivation from hibernation demands that initial contact is made via LGA 1.

Decoder 1 failed shortly after the Grigg-Skjellerup encounter, probably due to lifetime/ageing effects, the unit having received and processed nearly 200,000 commands. Full redundancy is provided by decoder 2, which had processed only approximately 5,000 commands at the time - although this now represents another mission single point failure.

Attitude & Orbit Control & Measurements Subsystem (AOCMS)

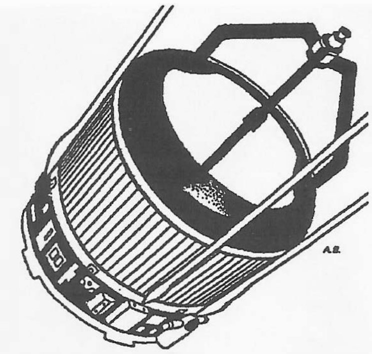
The star mapper (SM) baffle incurred dust impact damage during the Halley encounter, as a result of its vulnerable location protruding from the spacecraft main body. This has resulted in a "sun-blinded" viewing area where SMs are not useable. (It should be noted the SM has full electrical redundancy, but units share the same baffle). For periods when nominal SM operation is not possible, Giotto can no longer autonomously monitor and control its attitude, restricting allowable manoeuvres and requiring implementation of an alternative ESOC-derived attitude determination method. However, the orbit geometry throughout Grigg-Skjellerup operations was such that sufficient stars existed in the SM field of view to allow reliable unit operation.

All other AOCMS electronics and sensor units retain nominal performance, with full redundancy maintained. Software was demonstrated to be functional, and all manoeuvres and other autonomous operations performed correctly. However, constraints imposed by the Serv Conv 2 failure mean that no autonomous AOCMS reconfiguration capability is possible. Thus, in the event of an AOCMS failure, the spacecraft must be reconfigured by ground command before it can manoeuvre.

Reaction Control System (RCS)

No RCS anomalies are apparent, with nominal manoeuvre performance from main and redundant branches and all

Cometary Exploration: What Next?



Paradoxically, while Giotto's flyby of Grigg-Skjellerup was one of International Space Year's undoubted highlights, 1992 was not in itself the most auspicious year for the future of cometary exploration. One ambitious mission planned for the late 1990s was cancelled outright, while another came under ever increasing doubt.

NASA's Comet Rendezvous Asteroid Flyby (CRAF) mission was to have been launched in February 1996. The itinerary of the eight year-long mission included the reconnaissance of at least one main belt asteroid, and a rendezvous with a Jupiter class short period comet. Unlike all previous cometary encounters which each provided just one brief snapshot in time, the CRAF near encounter phase was expected to last 600 days, giving the spacecraft ample time to examine the comet in much greater detail and track its changing development as it swung around the Sun.

NASA undertook CRAF as a parallel development to the Cassini mission to Saturn. Because both spacecraft were to make use of almost identical Mariner Mk II spacecraft buses, it was possible to save over $500 million by combining both missions into a single programme. However, the combined project soon began to exceed its budget cap of $1.6 billion which had been imposed by Congress as a precondition of new start approval in 1989. Both CRAF and Cassini came perilously close to cancellation in the battle over Space Station funds which ensued in the summer of 1991. On this occasion both robotic missions were granted a reprieve, but in CRAF's case this proved to be only a temporary stay of execution. Barely six months later the decision was taken to sacrifice CRAF in order to secure the future of Cassini. Although the comet probe could claim marginally higher priority over Cassini, the Saturn orbiter is a collaborative venture with ESA (who are to provide the Huygens Titan probe) and it was this fact which probably tipped the decision in Cassini's favour.

With the Giotto mission having been such a spectacular success, ESA can claim to have forged a clear lead in the field of cometary exploration, but at the moment its plans for the future are not in much better shape than NASA's. In 1984 ESA proposed the Rosetta mission as the third cornerstone in its Horizon 2000 Space Science Programme. Rosetta represented the next logical step beyond NASA's CRAF. Its objective was to collect 10-15 kg of samples from a cometary nucleus and return them to Earth in their original state for detailed laboratory investigation. Because of its complexity, the mission was to have gone ahead as a joint collaborative venture with NASA.

A combination of problems on both sides of the Atlantic have, however, cast these plans in some doubt. Having been forced by budget constraints to scale back many of its long-term plans, ESA is currently studying several alternatives for a cheaper, all European project which may replace Rosetta as the cornerstone of its planetary programme. One option is for a comet rendezvous mission which would tackle many of the objectives previously assigned to NASA's CRAF. The other option would abandon cometary exploration in preference to a mission to attempt flybys of several main belt asteroids, and possibly a landing on a near Earth asteroid. A decision on which mission will be adopted as the third cornerstone is due later this year.

Darren L. Burnham

Health Check on Giotto (Continued)

commanded thrusters. Regular attitude correction manoeuvres to maintain HGA Earth-pointing were performed, in addition to orbit correction manoeuvres to optimise trajectories for Grigg-Skjellerup and the 1999 Earth flyby, and a final large precession manoeuvre on July 23 1992 to achieve the current hibernation attitude (which involved loss of ground link). This final manoeuvre was characterised by "spluttering" behaviour and rapid small variations in catalyst bed heater temperatures, consistent with a mix of hydrazine and pressurant resulting from the very small amount of propellant remaining.

Propellant consumption appeared to be nominal, indicating no significant leakage, degradation or chemical reaction effects. Only 4 kg (+/- 3 kg) of hydrazine remains (compared to 69 kg at start of mission) offering doubtful potential for a further reaction and Earth/Moon gravity assisted manoeuvre in 1999 and insufficient margin for a further cometary mission.

Thermal Control

Significant damage to external thermal control surfaces was inflicted by dust impacts during the Halley encounter, modifying thermal properties. Observed behaviour is consistent with damage caused by a combination of "sandblasting" of the dust shields and partial impairing/loss of external blankets and was taken into account in subsequent thermal modelling.

Orbit characteristics and heater power restrictions since Halley encounter have resulted in the spacecraft being subjected to hot and cold case temperatures well outside design limits for prolonged periods. In spite of these conditions, the only temperature-induced failures were CTU Proc 2 and Serv Conv 2.

Performance of active and passive thermal control elements remains nominal with temperatures consistent with predictions. The current hibernation attitude is set to guarantee sufficient electrical power and minimise thermal excursions.

Future Mission Prospects

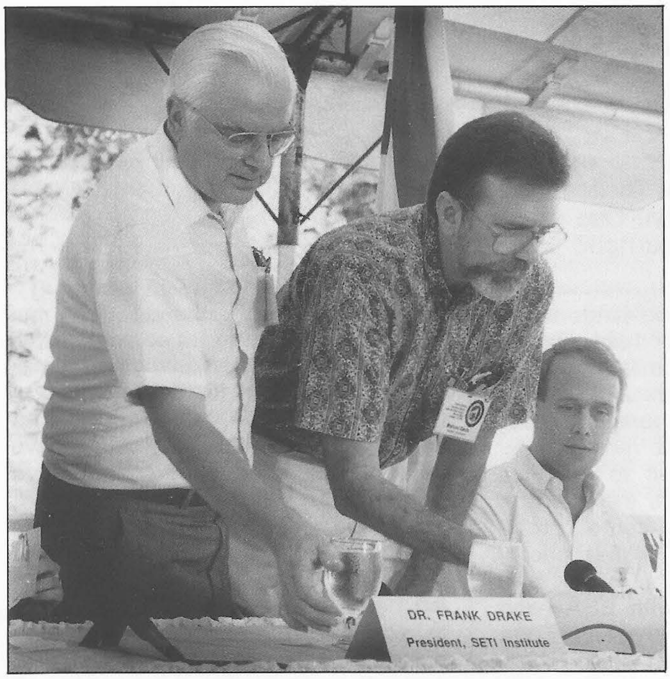
Thus, overall spacecraft health remains remarkably good. However, there are currently no plans for a further follow-on mission for the following reasons:

- The remaining propellant is insufficient for a third cometary flyby
- Power and thermal constraints will require temperature limit relaxations, switch-off of non-essential units and heaters, and a carefully optimised thermal strategy.
- The nature of the original Halley mission dictated a spacecraft design based largely on autonomy, with the capability to automatically reconfigure or manoeuvre to recover from a large number of potential on-board failures. This capability is now severely restricted, with ground intervention necessary for recovery.
- Factors such as reduced redundancy, extreme temperatures, dust damage, and a significantly extended lifetime (a 1999 reactivation will represent a 20-fold increase in the original design lifetime) make Giotto increasingly vulnerable to reliability, lifetime and ageing effects. This has influenced the current hibernation philosophy, whereby a minimum set of units remain operational and prime units are preserved by keeping them off whenever possible.

Acknowledgements

The author would like to acknowledge the assistance of Messrs H. Nye, N. Schmitt and A. Morani of the ESOC Flight Control Team and Messrs T.Kilvington and W. Johnson of the BAe Giotto Design Team

Ten-Year
NASA Listens for



In Arecibo, on October 12 1992. Left to right: Frank Drake, Mike Davis (Arecibo Observatory) and John Rummel (NASA).
Seth Shostak/SETI Institute

NASA began a decade-long project to search for signs of life in the Galaxy on October 12 1992, exactly five centuries after Columbus' arrival in the New World, New hi-tech radio receivers were activated by NASA in Puerto Rico and California, hoping to eavesdrop on interstellar transmissions. By October 13 1992, the space agency's newest SETI (Search for ExtraTerrestrial Intelligence) experiment had already sifted through more data than all previous efforts combined.

Dr Seth Shostak **of the SETI Institute writes for** ***Spaceflight*** **about the technical features of these new investigations and their chances of success.**

BY SETH SHOSTAK
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NASA's New Scheme

NASA's radio detection project, referred to as the High Resolution Microwave Survey (HRMS), is the modern incarnation of ideas of three decades ago. In these past 30 years, much thought has been expended on how to optimally conduct a radio search for extraterrestrials. The HRMS has adopted a conservative strategy, taking advantage of the best of our efforts to second-guess the aliens, while allowing for the uncertainty in our ability to do so. Consequently, the new NASA project is two-pronged. On the one hand, an intensive search will be made for signals in the direction of a thousand, nearby solar-type stars. Solid astronomical arguments suggest that these cousins of Old Sol are the stars most likely to have planets with earth-like environments. The so-called Targeted Search component of the HRMS will listen to these individual candidates, using large radio telescopes and relatively long observing times to gain maximum sensitivity.

On the other hand, it may be that we have to look farther than the stars on the Targeted Search's hit list, all of which are within 100 light-years of the Sun. Additionally, it could be that advanced cultures have migrated to locations beyond their native, presumably earth-like homes. Therefore, the second component of the HRMS, the Sky Survey, will use NASA's Deep Space Network tracking antennas to systematically observe the entire sky (albeit with less sensitivity than the Targeted Search).

Tuning in a Broader Band

This new SETI project, managed by NASA's Ames Research Center in Mountain View, California, is distinguished by more than its elaborate plan to both probe nearby stars and scan the sky. It will use modern digital receivers to cover a greater chunk of the radio dial than ever before. Most microwave searches have sampled the spectrum near the 1420 MHz emission line of neutral hydrodgen on the assumption that any advanced civilization will be aware of this naturally-generated "marker" frequency, and will have radio telescopes capable of receiving and (one hopes) broadcasting there.

But as far as possible, SETI researchers have tried to broaden their spectral coverage. They do this to account for both the unknown Doppler shift of any alien transmission and the possibility that the extraterrestrials might not wish to drown their own radio astronomers with a high-powered signal that was precisely at 1420 MHz. A frequent tactic is to extend observations toward higher frequencies, In the direction of the 1720 MHz line of the hydroxyl radical (OH). The 300 MHz band between the hydrogen and hydroxyl lines has been called the "water hole" (hydrogen and hydroxyl are the constituents of water), and the suggestion is made that, much as on Earth, alien creatures of whatever construction might wish to converge and commune there.

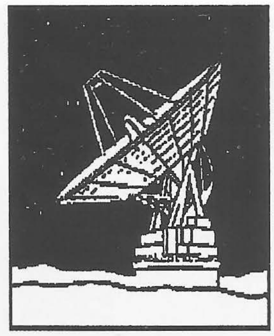
The HRMS covers more than the "water hole" however; it extends far into the "water wings." The Targeted Search will observe candidate stars at all frequencies between 1000 and 3000 MHz, and the Sky Survey will extend this upper bound to 10000 MHz.

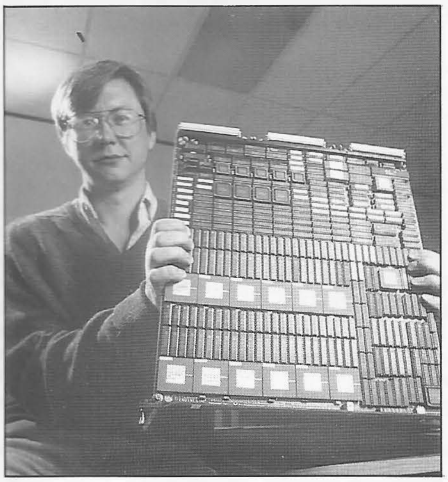
The extraordinary breadth of frequency coverage is complemented by very high spectral resolution. Individual channels for the Targeted Search and the Sky Survey will be as narrow as 1 Hz and 20 Hz respectively. These extraordinarily fine resolutions are necessary to delineate the sharp carrier signal expected from an artificially generated transmission. Narrow bandwidth not only distinguishes synthetic signals from those produced by natural processes in the Galaxy, it also ensures the highest signal-to-noise ratio for any given transmitter power. In other words, for any given transmitter power, narrow-band signals have the greatest visibility.

The special digital receivers of the HRMS sport tens of millions of channels. Consequently, a veritable avalanche of data pours out of the receiver when the telescope is observing. It is hopeless to try to store this torrent of numbers. Instead, on-board processors deal with the data as fast as they are produced. Dedicated computers examine the channels approximately once every second, looking for the telltale patterns of steady signals, and, in the case of the Targeted Search, ones that are pulsed as well. The detection computers are sophisticated enough to accept and record signals that slowly change frequency with time, as would be expected for a transmitter on a rotating planet, for example. Any patterns that are detected are flagged by the system for further confirmation tests.

These remarkable new digital systems, built by Silicon Engines, Incorporated (Palo Alto, California), John C. Reykjalin, Incorporated (Berkeley), the SETI Institute and Ames Research Center (Mountain View) for the Targeted Search, and by the Jet Propulsion Laboratory (Pasadena) for the Sky Survey, demonstrate

SETI Begins
Cosmic Intelligence





Jay Duluk, of Silicon Engines, Inc., holds one of the boards for the Targeted Search's Multi Channel Spectral Analyzer digital receivers. This device is capable of simultaneously listening on 15 million frequency channels.
Seth Shostak/SETI Institute

how far instrumentation for SETI has progressed since Project Ozma's 100 Hz-wide single-channel receiver, with its chart recorder output.

First Observations

The ten-year observing programme of the HRMS was kicked off in simultaneous ceremonies held at the mammoth 305-meter Arecibo Telescope in Puerto Rico, and the 34-meter antenna of the Goldstone, California Deep Space Communications Complex. At 3:00 pm Atlantic Time, the long, suspended line feeds of the Arecibo instrument were swung about to focus the instrument on Gliese 615.1A, a 7th magnitude star in the constellation of Serpens. At the same time, in the desert heat of California, the 34-meter antenna began scanning its first sky position.

After two months of observations, the Targeted Search has scrutinized 25 stars, and the Sky Survey has scanned 17 "sky frames," or strips measuring about 1 by 30 degrees. Only a small segment of the intended spectral coverage was observed however, with the Arecibo telescope sifting through about 300 MHz of bandwidth mainly in the "water hole" and near 2380 MHz, and the Goldstone dish taking advantage of an available X-band receiver to cover 40 MHz of frequency space near 8500 MHz.

That no demonstrably extraterrestrial transmissions were detected in the first series of observations is possibly disappointing to the wildly optimistic, but these initial HRMS efforts were critical tests of the equipment and data handling procedures. In particular, the increasing interference from mankind's own transmitters threatens to swamp attempts to find a weak signal that would betray an alien intelligence. These first observations were important in assessing the severity of the interference problem, as well as evaluating schemes to deal with it.

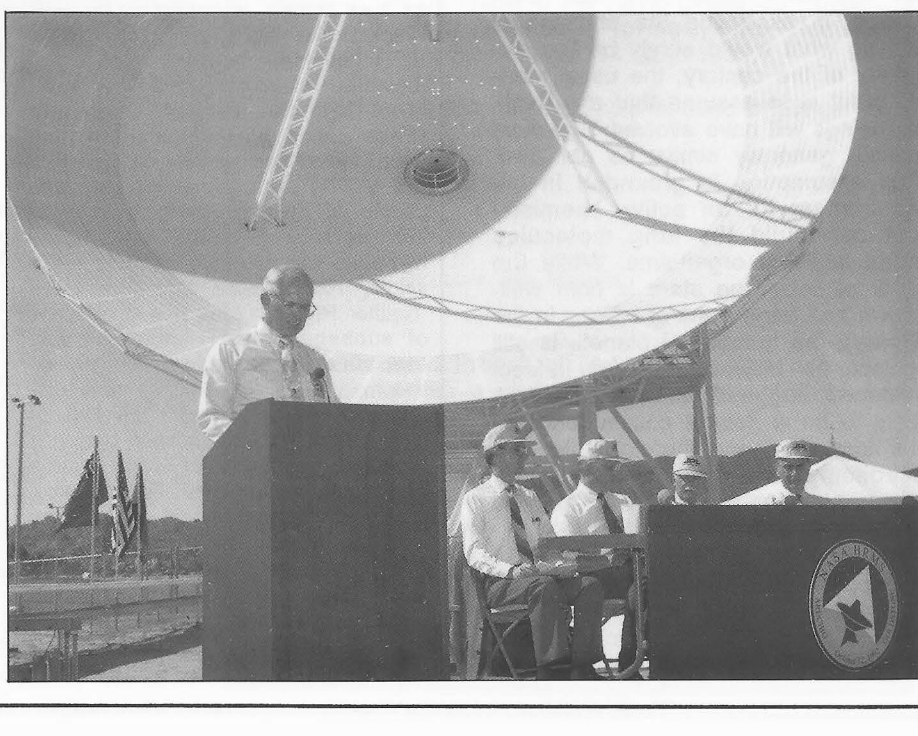
The Targeted Search discriminates against earthly emissions by first observing in the direction of the candidate star, and then making an observation of similar length pointed away from the target. The latter "off source" observation is compared with the "on." Signals seen in both are clearly due to terrestrial sources. But those seen only when the telescope is pointed at the star are subjected to further tests. This scheme serves to remove nearly all terrestrial radio frequency interference (RFI), in particular because the telescope's sensitivity to RFI is not very dependent on where it is pointed. The Sky Survey takes advantage of this fact by ignoring signals that appear in the same frequency channel over large portions of the scanned sky.

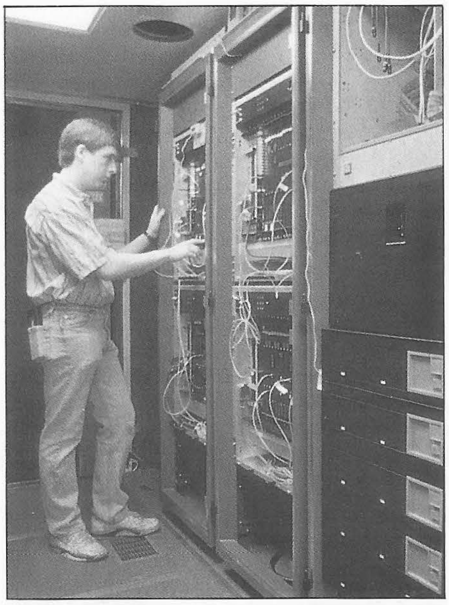
How Do We Know It's Real?

Finding a signal in the targeted direction but not in the comparison field is a necessary condition for a SETI success, but by itself is hardly a sufficient reason to alert the media. For example, a terrestrial transmitter that happened to be switched on for only a minute or so could pass this test and be mistaken for a true interstellar signal. The consequences of announcing a detection that turns out to be interference, an instrumental effect or a prank would be both embarassing and damaging, so SETI researchers rely on a slew of criteria to discriminate between extraterrestrials and earthlings. As mentioned, naturally generated Galactic noise is spread over a wide range of frequencies, so any narrow-band signal bespeaks an artificial origin. As mentioned, the Targeted Search is also capable of finding signals that slowly pulse on and off, another clue for intentionally produced emissions. And if the alien transmitter is on a rotating planet, or perhaps in orbit, we expect that the received signal will slowly drift in frequency due to Doppler shift (indeed, even if the transmitter is *not* accelerating with respect to us, the rotation of the Earth will introduce its own Doppler shift, and this is a nice discriminant against terrestrial transmitters).

A test required of all candidate receptions is that they can be found repeatedly. A signal seen only once is like a ghost seen only once: it is impossible to confirm that it is real. If E.T. is phoning, he had better stay on the line

Gary Coulter (NASA) addresses the crowds gathered at Goldstone for the start of the Sky Survey, on October 12 1992. Seated on the podium are Ed Stone (Director, JPL), Mike Klein and Sam Gulkis (JPL) and Carl Sagan (Cornell).
JPL





The interior of the mobile truck containing the digital receivers for NASA's Targeted Search. *Seth Shostak/SETI Institute*

a while, at least for a few days.

Finally, because of the possibility of pranks, even a signal that the HRMS finds over and over again will only become credible if it can be confirmed by other observatories.

Chances of Success

In the course of the next decade, the HRMS will make repeated use of the Arecibo and Goldstone antennas, as well as the 43-meter telescope in Green Bank, West Virginia and telescopes in Australia. As NASA scientists point out, this new experiment is many orders of magnitude more comprehensive than earlier searches. Does this mean that a detection is just around the corner?

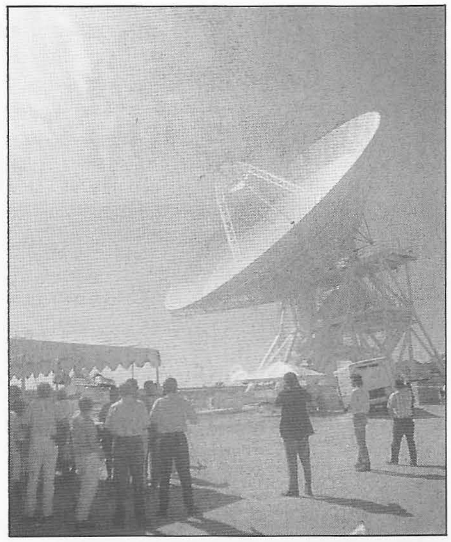
Alas, predictions of SETI success — even from those sporting long experience and impressive credentials — are still more guesswork than substance. In assessing the chances of making what would surely be the discovery of the century, the usual starting point is to assume that any thinking beings will have evolved on watery planets generally similar to our own. This assumption is grounded in the requirement for an active chemistry that can build the long molecules found in living organisms. While the stock of solar-type stars is both well-known and large (tens of billions in the Galaxy), the number of planets is still conjectural. However, recent indirect evidence suggests that planets are likely to be a natural consequence of star formation, and therefore plentiful. Astronomy is tending to favour the idea that earth-like worlds might be commonplace.

But whether life will spontaneously develop on such worlds is a matter of controversy among biochemists. On the one hand, some researchers point to the speed with which life began on Earth as evidence that biology was inevitable, given a suitable environment. On the other hand, there are experts who consider the creation of DNA-like molecules from the ingredients of the primordial soup is an event of extraordinarily low probability. In fact, plans to send manned spacecraft to Mars in the next few decades might help settle this disagreement. If a closer scrutiny of the red planet should reveal the fossil remains of even simple organisms, dating from the days billions of years ago when liquid water coursed over the Martian landscape, the force of argument would be on the side of those who believe that life is relatively easily started.

However, even if life has sprung up at many sites throughout the Galaxy, there remains the question of how often such biological beginnings evolve to creatures able to build a radio transmitter. After all, Nature's experiment with intelligence on Earth took nearly four billion years to get underway, and has (so far) lasted only a few million years. It may be that intelligence is an unlikely development. Furthermore, once a species reaches a certain level of technical development, it might self-destruct. In this distopian view, technological civilizations (which are after all the only kind we can detect) may be unstable, and of short duration. In that case, the chance that we may hear one becomes small. A mitigating argument against this rather dreary line of thought is to note that species tend to differentiate and proliferate. An advanced civilization might last long enough to spread itself, or at least its machinery, over interstellar space, thus rendering less likely the destruction of everyone or everything that could broadcast our way.

It is clear that these arguments soon lead away from astronomical and biological fact into the realm of speculative alien sociology. And just as clearly, such speculation will yield to knowledge only *after* the detection of other civilizations. In some ways, this situation is a bit like that of the Europeans of the 15th century trying to guess whether there might be a continent lying to the West, between Europe and Asia. In the end, only experiment could (and did) settle the matter.

And thus it seems particularly fitting that NASA's HRMS began on the 500th anniversary of Columbus' discovery of the Americas. The inaugural date was more than a tribute to discovery or the venturesome spirit. It was an acknowledgement of the power of experiment. Speakers at both the Arecibo and Goldstone ceremonies remarked on the scientific and philosophical significance of the new search. But the true drama of the moment was not in their words, but in what was happening. As large steel and aluminum antennas swung toward the cosmos, visitors who quietly sat by wondered at the audacity of our attempts, scarcely a half-century after the development of radio astronomy, to turn a fledgling science to the problem of answering a question that all previous generations could only ask.



The Goldstone 34 metre antenna on October 12 1992, as it began the Sky Survey. *A Danekas*

SETI History

In 1959, physicists Giuseppe Coconni and Philip Morrison noted that microwaves pass undisturbed through the gas and dust-filled reaches between the stars. The scientists were surprised to find that even a relatively modest microwave transmitter could produce detectable signals at interstellar distances. Could it be that advanced civilizations elsewhere in the Galaxy were filling space with radio traffic?

Although Coconni and Morrison weren't aware of it at the time, an effort was already underway to search for such signals. In the spring of 1960, Frank Drake made the first microwave SETI observations using a 26-meter diameter telescope at Green Bank, West Virginia. Project Ozma, as Drake called his pioneering experiment, lasted two weeks, during which the young astronomer observed a couple of nearby solar-type stars at the frequency of the 1420 MHz neutral hydrogen line. His receiver sampled a single, 100 Hz-wide channel.

Neither Project Ozma nor the dozens of subsequent SETI searches has ever turned up a single, confirmed extraterrestrial signal. But as researchers who are smitten with the idea of proving that we have cosmic company point out, the parameter space is large and mostly unexamined. For instance, in which directions should we train our radio antennas? And at what frequencies should we listen? Our failure to find extraterrestrial signals is widely believed to be the inevitable consequence of not trying hard enough.

Correspondence

Soviet Mars Mission Attempts

Sir, Reading Peter Pesavento's interesting letter in the February 1993 ***Spaceflight***, p. 59, I notice that he is sceptical about the reports of small rover vehicles on the Mars 2 and 3 landers in 1971.

I recommend the paper "From the Moon rover to the Mars rover" [1] by Chief Designer Alexander Kermurjian of the Industrial Transport Institute, Ministry of Defence Industries. He worked on Luna-13; Lunakhod 1 and 2; the Mars 2 and 3 rovers; Venera, Vega and Phobos landers.

A photo of the mini-rover appears in the paper. It was attached by a 15 m long tether to the lander and carried two scientific instruments for measuring the bearing strength and density of the soil.

Movement was by means of two mechanically operated "skis". Data were sent back to the lander by the cable. Bars on front of the walking rover allowed sensing of obstacles so the vehicle could step back and try another direction.

Mars 2 crash-landed and transmissions from Mars 3 ceased after just 20 seconds so the mini-rovers never saw service. Their existence was only revealed in 1990.

ANDY SALMON
West Midlands, UK

Reference

1. A. Kermurjian, "From the Moon rover to the Mars rover", *The Planetary Report*, July/August 1990, p.4.

Mir Lunar Orbiter?

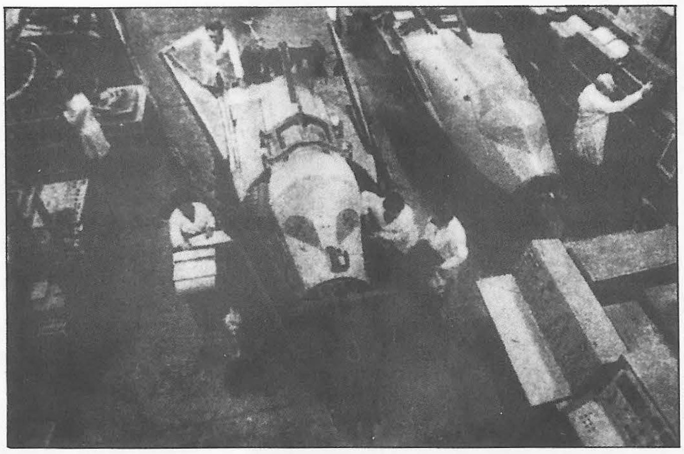
Sir, The "correspondence" on p. 56 of the February issue of ***Spaceflight*** deserves comment. Perhaps it is not such a good idea to place a human crew around the Moon in an old and worn-out Mir? Did the writer check-up on the "SSME and a small propellant tank" (which in any case should be a full-fledged man-rated high-performance interorbital vehicle)? The total Δv is about 4,330 m/s for the SSME, the mass ratio required is 2.65 resulting (for the 50 t Mir) in orbital all-up mass of about 180 t: the SSME is much too powerful! (A thrust of 60 t or so is needed). Stage storage time of H_2/O_2-propellants might need to be 4 days or more - no simple task either.

The "Earth-Moon loops" are not very stable, requiring propellant for trajectory control; and both the Shuttle and Soyuz cannot reach the near-parabolic speed required for the close-to-Earth part of the loop.

I would like to say it is a good idea but unworkable. I am afraid it is not even a good or reasonable idea.

Prof. HARRY O. RUPPE
Munich, Germany

Soviet Mini-Shuttle



Soviet Mini-Shuttles in assembly building.

Sir, In the October 1992 issue of ***Spaceflight*** I saw Mr Tomas Pribyl's letter with a picture of a model of the Soviet small unmanned shuttle (Kosmos 1374)). I enclose another photograph showing that spacecraft.

This photo was sent to me by A Chistyakov a year ago. Two such spacecraft are seen during installation of scientific and navigational equipment in the assembly building. According to my information this photo shows the second spacecraft that was launched in 1982 and its mock-up.

D. LEBEDEV
Ekaterinburg, Russia

Space-Related Music

Sir, I was very interested to read the recent correspondence following Mark Hempsell's article (***Spaceflight***, December 1992), regarding the extent of space related music. I noticed however that all the pieces referred to were in fact contemporary popular music.

The British classical composer Howard Blake (best known for his soundtracks for the films *The Snowman* and *Granpa*), has produced a very specifically astronautics-inspired piece entitled *The Conquest of Space*; which according to the sleeve notes on my copy was:-

> Commissioned by Astra, Europe's first 16-channel television satellite. This large-scale concert piece graphically portrays the launching of the rocket, the assent into space and an astral 'song for universal peace', starting quietly but building to a mighty conclusion in which all themes unite.

This piece was recorded in 1988 by The Sinfonia of London and released by CBS on the album *Granpa*. Perhaps some of your readers may know of the specific circumstances leading to the commissioning of the piece.

PAUL BRETTLE
Lancashire, UK

Space Related Songs

Sir, Concerning the search for space-related songs, there is also *Watcher of the Skies*, written in 1972 by Genesis.

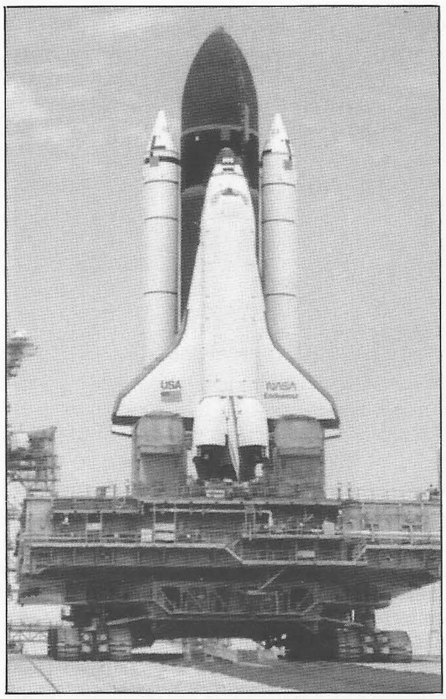
It is very interesting that ***Spaceflight*** has found a long list of space-related music in just two months. The idea of "space" has inspired also painters, poets, writers and, perhaps, architects.

So I think it is the right time to organise a Museum of Space Art.

MAURIZIO MORABITO
Pisa, Italy

A Good Year for

Kennedy Space Center successfully launched eight Space Shuttle missions in 1992, with five flights ending at KSC's Shuttle Landing Facility. Improved efficiency was the watchword for 1992. The launch countdown for all eight Shuttle missions began on the day set by NASA management at the Flight Readiness Review (FRR). Seven were launched on the date set at the FRR with one mission, STS-47, lifting off on the hour, minute and second scheduled. None had any major flight or ground support equipment (GSE) hardware problems and there were no in-flight anomalies associated with processing work. Additionally, Shuttle processing work hours, overtime, GSE open paperwork and vehicle problem reports were reduced significantly. In all, it was 'a good year for the Space Shuttle'.



STS-49 Rollout on 13 March 1992. *Ed Case*

The First International Microgravity Laboratory: STS-42

Launches in 1992 began with the Space Shuttle Discovery. On January 22, at 9:53 am EST, Discovery lifted off from Pad 39A on STS-42 carrying the first International Microgravity Laboratory, or IML-1. The international crew consisted of Commander Ronald J. Grabe, Pilot Stephen S. Oswald, Mission Specialists William F. Readdy, Norman E. Thagard, David C. Hilmers, Canadian Payload Specialist Roberta L. Bondar and German Payload Specialist Ulf D. Merbold.

The crew conducted experiments on the human nervous system's adaptation to low gravity and the effects of microgravity on other life forms such as shrimp, eggs, lentil seedlings, fruit fly eggs and bacteria. Low gravity materials processing experiments included crystal growth from a variety of substances such as enzymes, a virus, and mercury iodine. There were also 10 Get Away Special canisters on board, a number of mid-deck payloads and two Shuttle Student Involvement Program experiments.

Landing was on January 30 at Edwards Air Force Base, on Runway 22, on orbit 129, with a mission duration of 8 days, 1 hour, 14 minutes and 45 seconds.

Atmospheric Laboratory for Applications and Science: STS-45

The second flight of the year was STS-45 with the Space Shuttle Atlantis. This was the first launch of ATLAS-1, or the Atmospheric Laboratory for Applications and Science. Liftoff was on March 24 at 8:13 am EST from Pad 39A.

The seven crew members aboard included Commander Charles F. Bolden, Pilot Brian Duffy, Mission Specialists Kathryn D. Sullivan, C. Michael Foale, David C. Leestma and Payload Specialists Byron K. Lichtenberg and Belgium's Dirk D. Frimout.

The ATLAS-1 experiments were mounted on pallets in the orbiter's cargo bay and included 12 instruments from the US, France, Germany, Belgium, Switzerland, The Netherlands and Japan. Studies were conducted in atmospheric chemistry, solar radiation, space plasma physics and ultraviolet astronomy.

Other payloads included SSBUV, or the Shuttle Solar Backscatter UltraViolet experiment, one Get Away Special experiment and six mid-deck experiments.

Landing came on orbit 143 on April 2 at the Kennedy Space Center's Shuttle landing Facility, Runway 33. The mission elapsed time was 8 days, 22 hours, 9 minutes and 24 seconds.

Endeavour's First Launch: STS-49

The maiden flight of NASA's new Space Shuttle Endeavour, STS-49, produced the most spectacular mission of the year as its seven member astronaut crew set out to retrieve an Intelsat satellite stranded in low Earth orbit. Endeavour's first launch occurred on May 7 at 7:40 pm EDT from Pad 39B.

Aboard were Commander Dan C. Brandenstein, Pilot Kevin P. Chilton and Mission Specialists Bruce E. Melnick, Thomas D. Akers, Richard J. Hieb, Kathryn C. Thornton and Pierre J. Thuot. A new perigee kick motor was carried into orbit to be attached to the satellite. The capture required three EVA's and the first spacewalk ever by three astronauts. Eventually a special capture bar was attached and the 4.5 ton satellite was manoeuvred by the astronauts into the payload bay, mated to the solid rocket motor and

First British School Experiment Ever to Fly in Space

The first experiment ever to be sent into space by British schoolchildren was aboard the Space Shuttle Endeavour when it lifted off on September 12 1992 on mission STS-47. The payload, designed and made by girls of Ashford School in Kent, contained two experiments: Chemical Gardens and Liesegang Rings.

Both experiments can be performed in classroom laboratories. With Chemical Gardens, a container is filled with a sodium silicate solution and cobalt nitrate crystals added. Within minutes, brightly coloured chemical "plants" appear to grow, hence the name "Chemical Gardens". They grow vertically, just as real plants do. The Ashford girls wanted to see what would happen in the strange environment of space and so set a camera and flashgun to fire on commands from their inbuilt computer program to take about 100 pictures for study on return to Earth.

The phenomenon of Liesegang Rings has puzzled scientists for almost a century. When one chemical solution is placed on a gel containing another compound, a series of "rings" starts to appear and spread slowly outwards. Why? The girls want to see if the space environment will help to solve the enigma. As with the Chemical Gardens the rings were to be photographed (by a second camera taking 100 pictures at varying intervals over four days).

The school's Head of Science, Brian Stockwell, said "Building the space package was very difficult, but we were helped enormously by scores of British firms and individuals who contributed materials, knowhow and services. It was marvellous to find how keen British industry has been to help us achieve our goal. We shall pass on our knowledge to other schools once we have finished the job".

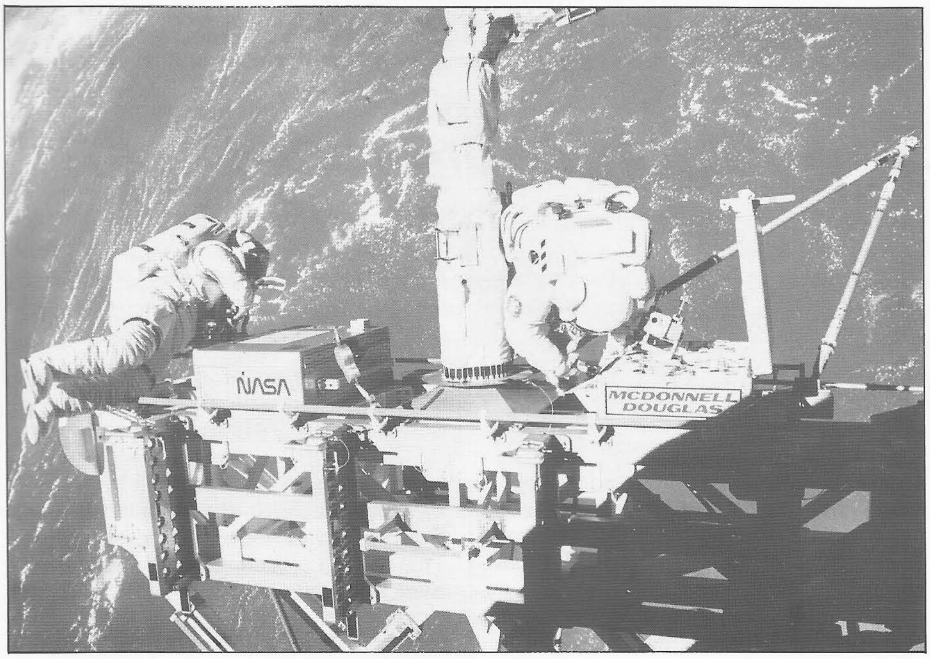
The Ashford School experiments came first out of 450 entries in a national competition run by Independent Television News (ITN) to fly an experiment in space. They were housed in a hatbox size container as a NASA "Getaway Special" (GAS). NASA have congratulated the school on their remarkable work, calling it "brilliant".

the Space Shuttle

then released back into space.

A planned EVA was also performed by astronauts Thornton and Akers as part of the Assembly of Station by EVA Methods (ASEM) to verify assembly and maintenance techniques for Space Station Freedom. The flight set a record for the longest EVA time for a single mission: 25 hours and 27 minutes. There were also three secondary "payload of opportunity" experiments.

Landing occurred on May 16 at Edwards Air Force Base, Runway 22, on Orbit 141. The mission elapsed time was 8 days, 21 hours, 17 minutes and 38 seconds. This was also the first use of the orbiter drag chute during landing.



Kathryn C. Thornton (left) and Thomas D. Akers are seen on the STS-49 mission's fourth period of extravehicular activity (EVA) as they work with components of the Assembly of Station by EVA Methods evaluation. The Multi-Purpose Support Structure (MPESS) is held aloft by Endeavour's remote manipulator system (RMS). *NASA*

First US Microgravity Laboratory: STS-50

The fourth launch of 1992 was the Space Shuttle Columbia, embarking on mission STS-50. The primary payload was the first United States Microgravity Laboratory, USML-1, a manned Spacelab module with connecting tunnel to the orbiter crew compartment. Launch occurred on June 25 at 12:12 pm EDT from Pad 39A. USML was a national effort to advance microgravity research in a broad number of disciplines.

Crew members included Commander Richard N. Richards, Pilot Kenneth D. Bowersox, Mission Specialists Bonnie J. Dunbar, Carl J. Meade and Ellen S. Baker and Payload Specialists Lawrence J. DeLucas and Eugene H. Trinh. The first Extended Duration Orbiter flight was also the longest Space Shuttle flight to date, lasting 13 days, 19 hours, 30 minutes and 4 seconds. The 11 primary experiments provided new information on the effects of long-term human stay in space. Three secondary experiments were also flown. Landing was on July 9, orbit 220, at the Kennedy Space Center on Runway 33.

Tethered Satellite Mission: STS-46

The Space Shuttle Atlantis embarked on the STS-46 mission in July for flight number five in 1992. Aboard were the European Space Agency's Eureca (European Retrievable Carrier) satellite and the Tethered Satellite System. Launch occurred on July 31 at 9:57 am EDT from Pad 39B.

Crew members included Commander Loren J. Shriver, Pilot Andrew M. Allen, Mission Specialists Franklin R. Chang-Diaz and Marsha S. Ivins, Claude Nicollier representing ESA as Mission Specialist, Payload Commander Jeffrey A. Hoffman and Payload Specialist Franco Malerba, representing the Italian Space Agency. Atlantis landed on August 8 on orbit 127 at the Kennedy Space Center on Runway 33. The mission lasted 7 days 23 hours, 16 minutes and 10 seconds.

Endeavour's Second Launch: STS-47

A detailed report of this mission begins on p.122. See also 'First British School Experiment Ever to Fly in Space' which appears opposite.

Columbia Mission: STS-52

The seventh launch of 1992 was Columbia on the STS-52 mission. The crew members included Commander James B. Weatherbee, Pilot Michael A. Baker, Mission Specialists William M. Shepard, Tamara E. Jernigan and Charles Lacy Veach and Payload Specialist Steven G. MacLean of Canada. The liftoff occurred on October 22 at 1:10 pm EDT from Pad 39B.

The primary objective of STS-52 was to deploy the Laser Geodynamic Satellite (LAGEOS II) atop an Italian Research Interim Stage (IRIS) upper stage booster. LAGEOS II was a joint effort between NASA and the Italian Space Agency (ASI). USMP-1, the first US Microgravity Payload, was also part of the Endeavour's STS-52 primary mission, conducting three experiments using weightlessness to research the potential of space manufacturing of new materials. There were also more than a dozen secondary experiments aboard, carried in the cargo bay and on Columbia's middeck.

Landing of Columbia was on orbit 159 at the Kennedy Space Center on November 1, Runway 33, with a mission elapsed time of 9 days, 20 hours, 56 minutes and 13 seconds.

Last Mission with Classified Payload: STS-53

The last flight of 1992 was that of the Space Shuttle Discovery, launched on a mission for the Department of Defense. This was Discovery's fifteenth launch, the most for any orbiter in the fleet. Launch from Pad 39A was at 8:24 am EST on December 2. While the primary payload was classified, there were a dozen unclassified secondary payloads aboard.

The STS-53 astronauts included Commander David Walker, Pilot Robert Cabana and Mission Specialists Guion Bluford, Michael Clifford and James Voss.

Landing was diverted to Edwards Air Force Base because of cloud cover at KSC, with a landing on Runway 22, orbit 115. Mission elapsed time was 7 days, 7 hours, 19 minutes and 17 seconds.

In the Operations and Checkout Building, the STS-47 flight crew enjoys breakfast before suiting up and heading for the Space Shuttle Endeavour at Launch Pad 39B. From left are Mission Specialist N. Jan Davis, Payload Commander Mark C. Lee, Pilot Curtis L. Brown Jr., Mission Commander Robert L. Gibson, Mission Specialist Jay Apt, Science Mission Specialist Dr Mae C. Jemison, and Payload Specialist Mamoru Mohri. The countdown clock is ticking toward a scheduled liftoff at 10:23 am EDT. *NASA*

Two-Team Crew for 24-Hour Work-Day

The Space Shuttle Endeavour was successfully launched from the NASA John F. Kennedy Space Center's Launch Complex 39B on September 12, 1992.

The STS-47 mission's primary payload was the Spacelab-J laboratory; a cooperative project of the United States and Japan. The launch marked the 50th launch of the Space Shuttle program and the second launch of the orbiter OV-105 Endeavour.

BY ROLOEF SCHUILING
at the Kennedy Space Center

Endeavour's previous flight was the history making STS-49 Intelsat satellite repair mission and following a successful landing at Edwards Air Force Base in California, it returned to the Kennedy Space Center (KSC). On May 31, 1992 it was transported into the Orbiter Processing Facility (OPF) work bay 3 where it spent 78 days for post-flight evaluations and preparations for its next mission. The orbiter's main engines were replaced with engine 2026 installed in the no. 1 position, engine 2022 in the no. 2 position and engine 2029 in the no. 3 position.

Spacelab Experiments

On July 14 the main mission payload, the Japanese Spacelab SL-J was installed in the payload bay which also carried a GAS Bridge Assembly support with 12 Get Away Special (GAS) canisters. Ten of the GAS canisters contained experiments and two were ballast.

Spacelab-J included 24 materials science and 20 life sciences experiments. Of these, 35 were sponsored by the Japanese NASDA agency and 7 were from NASA, while 2 were collaborative efforts.

Life sciences investigations included experiments on human health and experiments to prevent or minimise the adverse effects of living and working in space. Among the test subjects of the life sciences experiments were the crew members themselves; Japanese Koi (carp) fish; cultured animal and plant cells; chicken embryos; fruit flies; fungi and plant seeds; and frogs and frogs' eggs.

The Shuttle orbiter's middeck area also carried experiments dealing with combustion and hornet comb building in microgravity.

Assembly and integration of the Spacelab-J payload had begun at KSC as early as January 1991. In early 1992 the experiment racks were assembled on a Spacelab floor for testing. In March and April 1992 the Spacelab module shells were taken from STS-42's International Microgravity Laboratory, their previous mission. The rack and floor assembly for STS-47 was then inserted into the Spacelab's two-module structure and integrated Spacelab level tests were carried out between April and July.

The assembled Spacelab-J and the GAS Bridge Assembly were transported to the OPF on July 14 for installation in the payload bay. The tunnel which leads from the orbiter middeck to the Spacelab was installed on July 24. The payload bay doors were closed on August 11 in preparation for the trip to the Vehicle Assembly Building (VAB).

Launch Preparations

Endeavour was moved by transporter to the VAB transfer aisle early on August 17. The next step would have involved lifting the orbiter that day and mating it to the External Tank/Solid Rocket Booster combination. This was delayed several days however, as one of the VAB's 250 ton cranes had experienced a recent control anomaly. An investigation board reviewed the incident in detail before allowing a second crane to lift the STS-47 orbiter. The lift and mate operation occurred overnight on August 19-20.

Preparations were completed for rollout to Launch Complex 39B and the STS-47 Space Shuttle was moved to the launch pad on the morning of the 25th. The Shuttle was hard-down by 10:15 am and the Rotating Service Structure was in place alongside the Shuttle by 1:00 pm of the same day. By evening, the orbiter was powered up for tests of the pad interfaces. Also on the 25th, the flight crew arrived in preparation for the countdown simulation. The crew travelled to KSC earlier than was normal in order to avoid a hurricane which was moving towards the Gulf coast.

The launch crews at KSC began a countdown simulation for STS-47 on the morning of August 27 which lasted for 27 hours. On Friday the 28th, the crew took part in the final phase of the countdown simulation.

Over the weekend, the launch crews performed main engine readiness and leak tests and prepared for the loading of hypergolic propellants which took place in the first part of the ensuing week.

Ordnance operations on the 5th were followed by a holiday weekend, after which, on September 8, preparations for the countdown were in full swing. The launch countdown was picked up at 3:00 am on Wednesday September 9 at the T-43 hour point so that built-in holds would bring the count to a planned T-0 at 10:23 am on Saturday the 12th.

At T-11 hours a 21 hour 3 minute built-in hold began at 11:00 pm on the 10th. Stowage operations in the Spacelab module were accomplished by lowering a technician, via a hoist and cable, down through the now-vertical Spacelab-to-cabin tunnel. At 11:00 am on Friday the 11th, the Rotating Service Structure was moved away from the orbiter midbody.

Following the completion of this extended built-in hold at 8:03 pm on the 11th, preparations for final loading of the Shuttle's external tank with liquid hydrogen and oxygen were in progress.

The crew, who had arrived at KSC on the 9th, were awakened in two groups with the Blue team being awakened at 4:58 am and the Red team at 5:28 am to facilitate easier transition to their on-orbit timelines. A 2 hour built-in hold lasted from 5:03 am to 7:03 am and with the completion of the hold the crew departed their quarters for the launch pad.

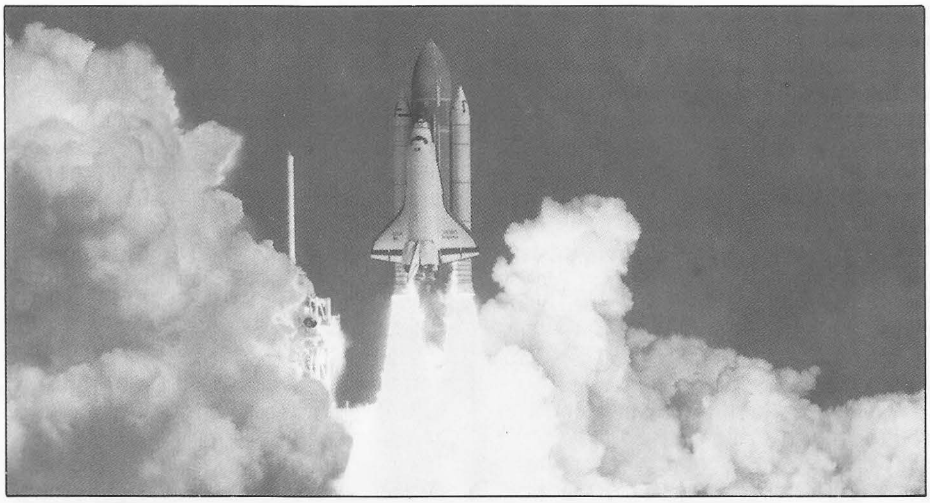
The final hours of the countdown proceeded as planned. Built-in-holds of 10 minutes each came at the T-20 and T-9 minute points. T-0 came at 10:23 am on September 12. The time and date which had been set at the Flight Readiness Review.

STS-47's launch and ascent followed the usual 57 degree inclination pattern with Solid Rocket Booster separation at 10:25:07, followed by Main Engine cutoff at 10:31:34 and External Tank separation at 10:31:52 am. At 356 minutes 12 seconds into the flight the Orbital Manoeuvring Engines were fired to circularise the orbit. Preparations were made for orbital operations and the shuttle payload bay doors were opened. STS-47 had begun with an on-time liftoff and ascent.

Flight Day One

The flight crew began operations to ready their Shuttle orbiter for its mission operations. The Ku-Band antenna was swung out to facilitate communications and the Spacelab-J payload was activated.

The crew was divided into two teams, termed "Red" and "Blue", so that 24-hour-days could be worked. In order to begin the two twelve-hour work shift schedules immediately after the mission began, the first sleep period for the Blue team began at three and a half hours into the mission. At ten hours into the mission the Blue team awoke and began activities.



A smooth countdown culminates in a perfect launch of the Space Shuttle Endeavour at 10:23:00 am EDT on 12 September 1992 from Launch Pad 39B. *NASA*

Initial emphasis in the Spacelab module was on Materials Sciences experiments. Japanese NASDA scientists at NASA's Marshall Space Flight Center operations were able to watch real-time images of the experimental activity, including mission specialist Mae Jemison's Spacelab operations of the Gas Evaporation In Low Gravity experiment, which examined the mechanism of particle formation in a gas atmosphere as metal evaporation sources were heated in a spherical chamber known as the Gas Evaporation Facility. Jemison activated the Space Acceleration Measurement System (SAMS) which measures and records low level accelerations in space and has flown on other Shuttle missions. Later, Jemison and Davis worked with Life Sciences experiments including studies of microgravity effects on the development of frog embryos and radiation effects on fruit fly larvae.

On the flight deck, Jay Apt began setting up the Shuttle Amateur Radio Experiment (SAREX) equipment.

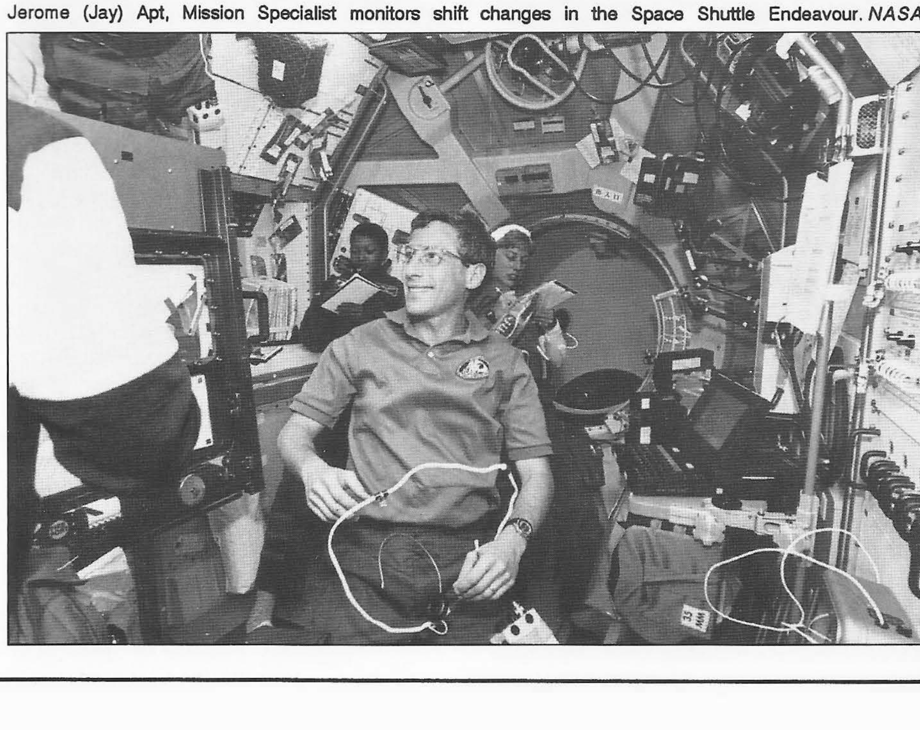
As the first day in space came to a close, Endeavour was orbiting the Earth in a 162 by 166 nautical mile orbit and maintaining a gravity gradient attitude.

Flight Day Two

Pilot Curtis Brown worked with experiments such as the Protein Crystal Growth experiment which is designed to grow flawless crystals in space, including a hormone receptor which is used in cancer research.

Mark Lee worked with the carp fish experiment which studied visual responses to stimuli in a microgravity environment and performed injections of female frogs to stimulate ovulation. Later, Davis and Jemison would

Jerome (Jay) Apt, Mission Specialist monitors shift changes in the Space Shuttle Endeavour. *NASA*



perform operations to fertilise the resultant eggs which would be studied at various stages of their growth. Half of the developing eggs were placed in a centrifuge and the remainder developed in microgravity. During the Blue team shift Davis worked with the Continuous Heating Furnace facility and Jemison, assisted by Apt, worked with the Frog Embryology studies. Apt also was able to send down to Earth video images of a daytime pass over Japan with Tokyo clearly visible.

Flight Day Three

A power cut at the Houston Mission control during the afternoon took down all displays and communications with Endeavour were lost. The Marshall Space Flight Center's payload operations center remained in contact with the orbiter and no science data were lost. The power cut was traced to a faulty switch which had been thrown to return power to the main commercial electrical power supply system after a precautionary change to backup generators had been made when thunderstorms were in the area. Power was reestablished and communications restored to Endeavour within seven to nine minutes.

During the Blue team activity Jemison performed experiments involving acoustic levitation of oil droplets to study containerless fluid behaviour and worked with a chicken embryo experiment studying weightlessness effects. She also stopped development of some of the frog embryos previously fertilised and gave the ground scientists a video look at frog eggs which had been fertilised on the ground prior to the launch and were now hatching into tadpoles under weightless conditions.

Davis talked to students in Huntsville, Alabama; home of the Marshall Space Flight Center, *via* the SAREX communications gear.

Jay Apt participated in a radio programme during which he answered questions from listeners who phoned into the programme. Apt also reported that the computerised SAREX equipment had had over 1,800 contacts from radio amateurs on the ground.

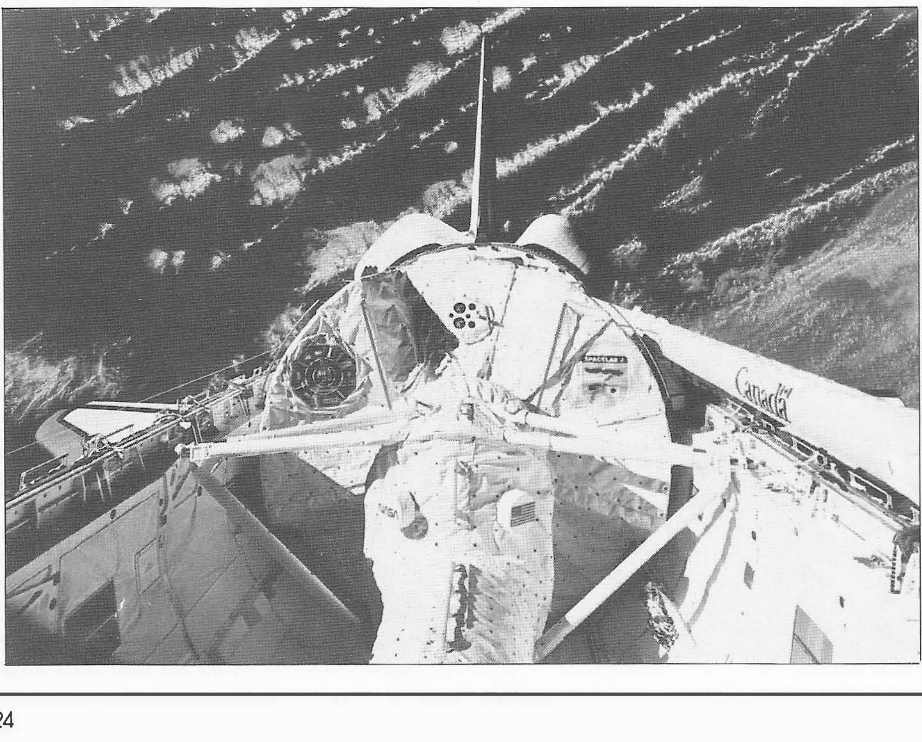
Flight Day Four

Gibson and Brown made observations of a middeck experiment; ISAIAH, an Israeli Investigation into hornet nest building in microgravity. They reported that the hornets appeared healthy but their nest-building activity was not organised as would be expected. Experimenters noted some condensation in the experiment and Gibson and Brown rigged a fan hook up to attempt to alleviate the condensation by increasing the volume of air going through the experiment as the hornets natural environment is warm and dry. The fan was removed from one of the crew's launch/reentry partial pressure suits and hooked to a vent at the front of the experiment. The makeshift air supply worked well and was used several times throughout the mission.

Jay Apt worked with Mission Control to recover the use of a Payload General Support Computer which had developed a display screen problem. Apt reported a successful contact, *via* the SAREX, with a group of students in Honolulu, Hawaii, the sixth such contact Endeavour's crew had made with school groups so far in the mission.

Ground controllers at the Johnson Space Center who were monitoring Endeavour's performance reported that by this stage of the mission sufficient consumables had been conserved to enable it to be extended one day if desired. The science team began an assessment to determine if the extension should be made.

Part of the science module which housed eight-days of science research in support of the Spacelab-J mission taken with a 70mm camera aimed through the aft flight deck windows. *NASA*



Flight Day Five

During the day mission controllers and the science team decided to add an additional day to the flight. The STS-47 crew had accumulated sufficient surplus electrical power and breathing air for 25 hours over and above the standard two-day contingency allowance.

Gibson and Brown continued to run the fan, periodically, directing additional air into the ISAIAH experiment. The fan had reduced the humidity from 98 to 78 percent and continued to be used throughout the flight.

Lee and Mohri worked with Samarskite crystals using the Image Furnace facility to study slow-cooling float zone and travelling-solvent float zone methods in microgravity. Mohri delivered a microgravity lesson to Japanese schoolchildren on the ground.

Apt worked with the Solid Surface Combustion Experiment in the Endeavour middeck. He also continued to take Earth observation photographs and reported that, so far, Endeavour had received over 5,700 contracts from ham radio operators using the SAREX equipment.

Jemison and Davis continued their work in the Spacelab module, with Jemison participating in a live television interview from her hometown of Chicago. Davis also spoke to her former hometown of Huntsville, Alabama, where she lived while working for eight years at the Marshall Space Flight Center prior to being selected as an astronaut.

Crew members participated in a press conference, answering questions from reporters at the Kennedy and Marshall Space Centers.

Flight Day Six

Gibson and Brown continued to observe and video tape the ISAIAH hornet nest building. The hornets' activities appeared to be disorganised by the weightless environment. The experiment contained 18 chambers of various sizes, each containing a group of hornets.

In the Spacelab module Lee and Mohri continued studies of the carp fish and material sciences experiments and Apt continued photography as part of the Space Shuttle program's project to document Earth from orbit.

Flight Day Seven

Friday, September 19 had originally been planned as the day before landing. In order to protect the capability to land on Saturday as initially planned if the need developed, the crew per-

The STS-47 crewmembers assemble for their traditional inflight portrait in this 35 mm frame photograph in the science module aboard the Earth-orbiting Space Shuttle Endeavour. The seven spent eight days in space in support of the Spacelab-J mission. *NASA*

formed pre-landing tests of the Endeavour systems.

The movable surfaces of the wings and tail of the Endeavour, which are used when it reenters the atmosphere, were checked out in preparation for the Kennedy Space Center landing, now rescheduled for Sunday, the 20th at 7:19 am.

Later on Friday morning Gibson and Mohri took part in a conversation with the Prime Minister of Japan and the head of the Japanese National Development Agency.

About 3:00 pm on Friday, mission commander Gibson asked ground controllers to look at the port side of Endeavour's rudder using the payload bay video camera. He reported observing a small area of insulation protruding 2 to 3 inches from the hinge line. Engineers and controllers on the ground evaluated the condition to ensure no hazard to the landing would exist.

Mission specialist Lee and Payload specialist Mohri made additional microgravity observations in the Spacelab as the extended flight provided additional time for scientific studies. Davis and Jemison were also able to take advantage of the additional time on-orbit to work with the Spacelab module experiments.

Flight Day Eight

During Saturday, September 19, Mission Control finalised plans for the STS-47 landing at KSC the following morning. Two landing opportunities existed; one on orbit 126 at 7:19 am and another on orbit 127 at 8:53 am.

The Red team wound up their last full work day of the mission about 4:00 pm Saturday. Lee and Mohri had continued Spacelab operations while Gibson and Brown began some of the middeck experiment deactivation work.

Later, the Blue team wound up their last science work with the Spacelab-J experiments and began closing out the module and stowing experimental equipment. The Spacelab module was then deactivated in preparation for the landing.

Early morning rain showers in the KSC landing facility area caused controllers to choose the second of the two possible landing attempts.

The orbiter Endeavour, preceded by its characteristic double sonic-boom, successfully landed at the Kennedy Space Center. The main landing gear touched down on runway 33 at 8:53:24 am. The drag chute was deployed before the nose landing gear touched down and the drag chute decelerated the orbiter before the chute was jettisoned to avoid entanglement with the orbiter engines. Nose gear touchdown was at 8:53:41 am and wheel stop was at 8:54:11 am.

The total mission time was 7 days, 22 hours, 31 minutes and 11 seconds. Endeavour covered 3,310,922 miles during its flight, the 50th in the Shuttle program.

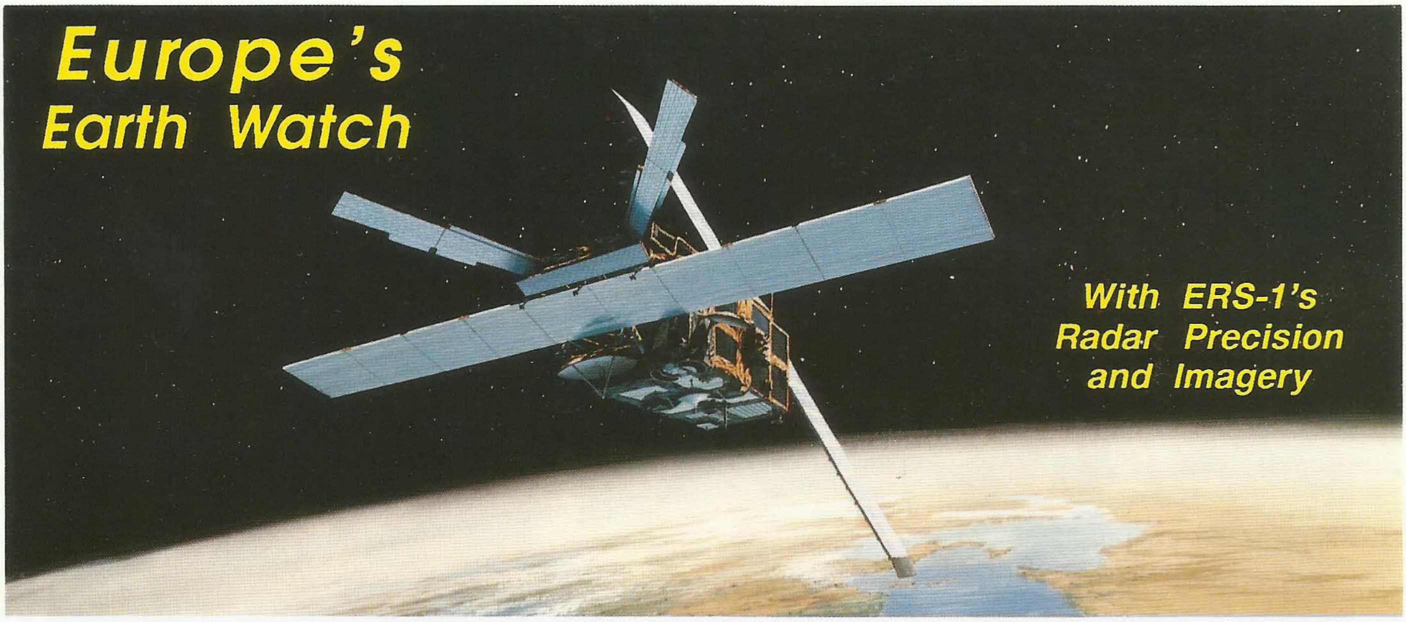
Following safing of the Shuttle and after the crew left the Endeavour, the orbiter was moved to the Orbiter Processing Facility by 3:47 pm.

About The Crew

First Married Couple in Orbit Together

The mission carried a crew of seven astronauts and included a Japanese astronaut. The mission was commanded by veteran Robert L. "Hoot" Gibson 45, who flew previously as pilot of STS-41B in 1984, and as commander of missions STS-61C in 1986 and STS-27 in 1988. Mission pilot was Curtis L. Brown, Jr., 36, who was making his first space flight. Veteran mission specialists included Mark C. Lee, 40, who flew first on STS-30 in 1989 and Jay Apt, 43, a veteran of STS-37 in 1991. Also making their first space flights were mission specialist N.Jan Davis, 38, and science mission specialist Mae C. Jemison, 35. The title *science mission specialist* denotes a career astronaut who performs the tasks of a payload specialist. A *payload specialist* is a career scientist or engineer who is selected by peers, employer, or country to conduct specific experiments. The payload specialist for the mission was Mamoru Mohri, 44, who was selected as a payload specialist by the National Space Development Agency of Japan. Mission specialists Lee and Davis are married and were the first married couple to fly on the same mission.

As on previous missions with 24 hour work schedules on-orbit, STS-47's crew were divided into two operational shifts. The Red Team of Brown, Lee, and Mohri formed one team and the Blue Team of Apt, Davis and Jemison formed the other. The mission commander, Gibson, followed an unrestricted schedule.



Artist's impression of ERS-1. Both the spacecraft platform and radar instrumentation were designed and manufactured by Matra Marconi Space. *Matra Marconi Space*

From Oil Slicks to Green Shoots

All in the Day's Work for ERS-1

'You cannot manage until you can measure' is an old management adage, but it now has a space age equivalent: 'you cannot measure until you calibrate'. And it is the exceptionally precise level of calibration achieved for all ERS-1 instruments that has made possible the unique and outstanding results that are currently being studied. When ERS-1 was launched the scientists had high hopes, but they did not expect that the data would be so exact in so many fields of activity.

BY NORMAN LONGDON
ESA/ESTEC, The Netherlands

Ocean Vista

Extreme climatic conditions are often driven by changes in ocean currents. ERS-1 is giving, on a month by month schedule, exact details of critically important ocean currents such as those associated with 'El Nino' in the Pacific. Images of the ocean features are taken by the SAR (Synthetic Aperture Radar) at surface wind speeds within the four-to-ten metres a second range for the oceans east of Australia, the east and west Canadian coastal waters, the Norwegian sea, the English Channel, the sea around Iceland and Denmark, the Gulf of Alaska and the Mediterranean Sea. This has given confirmation of the theory on ocean wave imaging mechanisms and more detailed database of the global wave height fields is being built up.

From the radar altimeter data a new understanding emerges of the mesoscale short time scale phenomena, especially within strong currents. The 'El Nino' phenomena occur approximately every seven years, during which waters from the western Pacific move east, and change the direction and temperature of the ocean close to the South American coast. This has serious climatic consequences, producing excessive rainfall in some areas, and drought further away. Such activity occurred in 1991/1992 and has been observed by ERS-1.

The SAR has proved its ability to detect and monitor erosion and sediment transport phenomena along the coast, and also coastal profile changes. The SAR has also revealed bathymetric features in shallow waters, and this facility has been related to the coastal and underwater geological features for an area in the southern North Sea, just off the English coast.

It has been commented on before, but the very scope demands reiteration - *ERS-1 covers regularly at three-day intervals more of the world's oceans than other recording methods have managed in the recorded history of the human race.*

Frisian Islands (The Netherlands). The first ERS-1 SAR image acquired at Fuccino, Italy in July 1991. Coastal erosion, sediment transport and bathymetric features in shallow waters are revealed. *ESA*

Ice Vista

It is easy to understand that polar ice and sea ice can give early indications of climatic changes. It is not so easy to provide information on the ice, but now, thanks to ERS-1 scientists have

an excellent new insight into the structure and distribution of ice on a global scale. ERS-1 has been a catalyst in the creation of large and very active international ventures for the study of sea ice in the Arctic and the Antarctic, with additional deployment of ships, aircraft, and in-situ measurement stations to provide 'ground truth' data. The results have been a confirmation of ERS-1's ability to be a major tool in the research and monitoring of ice concentration, ice classification and ice motion. The radar altimeter in its 'Ice mode' has achieved an accuracy of better than three metres in estimating the height of the ice sheet. A digital elevation model of Greenland has already been presented with greatly improved accuracy.

Wind and Wave Vista

The meteorologists are very happy that ERS-1 can, and is providing them with continuous and detailed information on surface winds and waves that they can build into their weather forecast models. They are using these data in real time in their models. ERS-1's data are not only comparable with those obtained from ships, but they allow global fields of wind and waves to be derived; an ability not shared by ship-borne observations. The real advantages to meteorologists will become more apparent when they have more fully digested the uses to which such accurate and frequent data can be put.

Shipping Vista

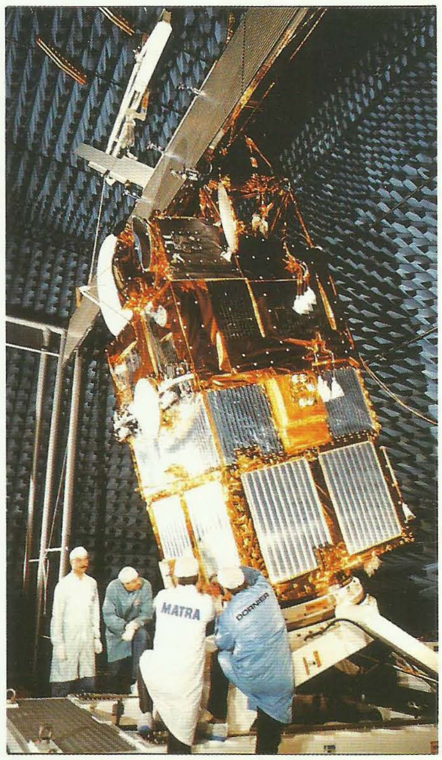
The uses to which shipping companies can put ERS-1 data are still the subject of experimental studies. It is clear however that ERS-1 can assist in choosing shipping routes, especially in ice-infested regions, as has already been shown in experiments in both the North West and North East Passages. In 1991 the Astrolabe experiment was successfully concluded along the North East passage, and in 1992 the Frontier Spirit cruise ship was guided along the North West passage. Detection of ships and sea traffic monitoring, dependent on both sea-state conditions and the size of the ships have been successfully demonstrated. For many environmentalists the dangers to marine and other life coming from oil leakage or oil spills is still extremely serious. ERS-1 has demonstrated its ability, under certain sea-state conditions, to detect such pollution.

Land Vista

Quick, accurate and regular images that, irrespective of the weather conditions, monitor such important phenomena as the cutting down of forests, crop growth and desertification are now available from ERS-1. Seasonal and even longer temporal spans of some phenomena associated with land processes have meant that not all land data analysis is at an advanced level. However the important differentiation between crop types has been successfully demonstrated. It is not yet possible to draw definitive conclusions on classification of forest species, but results so far are encouraging. Other preliminary results with an exciting potential include the combination of SAR and optical images for analysis of tectonic faults and desert features, the practicability of using SAR for hydrographic mapping of rivers, swamp areas, drainage basins etc, as well as for the assessment of snow cover and glacier monitoring.

New Vista

The very stability of the ERS-1 SAR and the orbit allows new products including three-dimensional maps of the topography with an accuracy of better than five metres in height. It is thought that this will also result in highly accu-



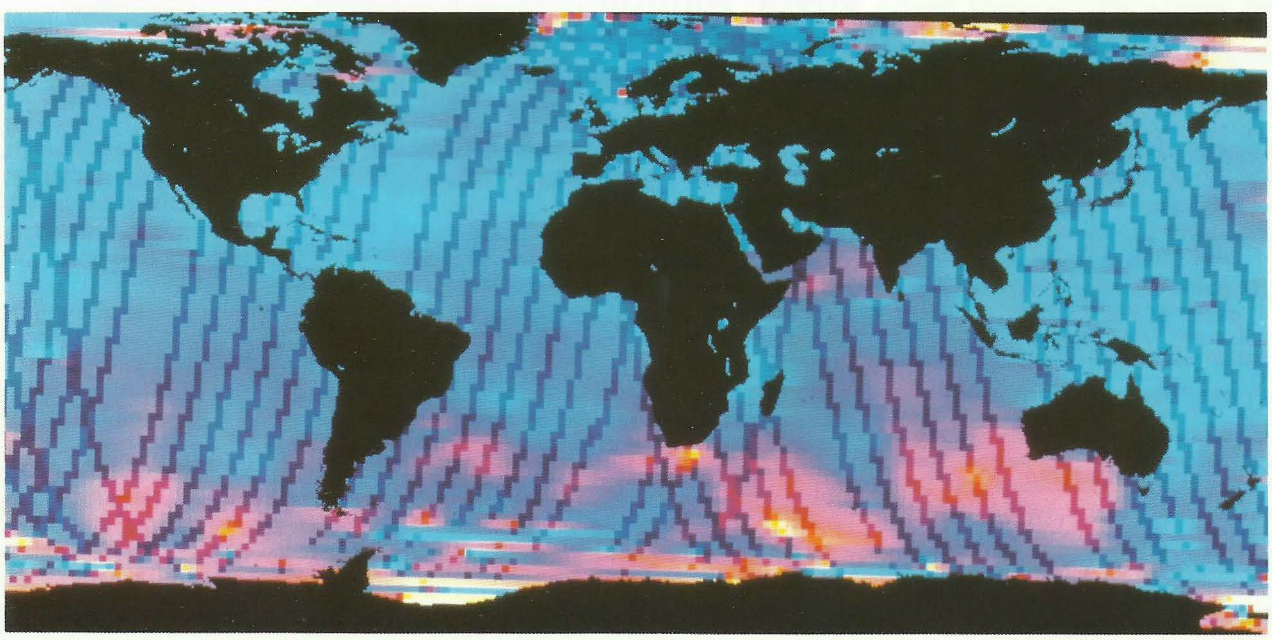
ERS-1: the first in a series of environmental monitoring satellites planned by the European Space Agency and Matra Marconi Space. *ESA*

rate detection of local movements in the Earth's crust.

Conclusion

At a time when the world is becoming increasingly aware of the dangers to the environment, and the need for accurate, regular, and continuous global coverage if we are to begin to understand that environment, ERS-1 is leading the field. This was a point not lost on the European states that contribute to the European Space Agency, and it was well reflected in the decision to support follow-on Earth observation activities even during a time of retrenchment.

Global wave heights: blue - 1-2 m, red 5 m, yellow 12m. ERS-1 radar altimeter. *ESA*



SPACE SECTOR

The Future of SAR

The Defence Research Agency in Farnborough is one of the premier research and development establishments in Europe and has been a leader of UK space activities since the launch of the first satellite in 1957. It is currently leading the UK space research programme on behalf of the MoD and the BNSC with the development of space instruments, data handling techniques and the infrastructure required by the UK to use satellite images operationally.

Handling and Interpreting the Data

The DRA, with Matra Marconi Space as the prime contractor, has been active in the field of Synthetic Aperture Radar (SAR) research for many years. The launch of the ERS-1 satellite, carrying an Active Microwave Instrument (AMI), which can be operated in SAR mode, has added a significant stimulus to the work.

If ERS-1's SAR data is to be used operationally, a fast SAR processor may be required to generate imagery from the radar returns in near real-time. Features can then be extracted from the imagery and provided directly to end users in near real-time over low bandwidth land lines. The DRA managed the building of the first European satellite SAR processors to handle data from Seasat and SIR-B, as well as ERS-1 and various airborne radars. A prototype image analysis work-station has also been developed to demonstrate near real-time maritime applications (e.g. ship detection and tracking, sea ice monitoring etc.) using ERS-1 SAR data.

One of the main advantages of space SAR is its all weather, day and night imaging capability, but the resultant data are often difficult to interpret and much of the DRA's research is aimed at obtaining a better understanding of the mechanisms by which surface features are imaged by space based radar.

UK Facilities Available

The West Freugh Satellite Ground Station

The Space and Communications Department at the DRA recently completed the West Freugh satellite ground station which is being used to receive data from ERS-1. The station comprises a large tracking antenna in a radome and a new single-storey, purpose-built building to house the receiving and data recording equipment. The station has dual feeds, providing the capability to receive signals at both X and S-band. A transcription facility has been installed to provide data in computer readable form and a data communications network will come on-line in May, providing a direct link to Farnborough. The site was selected to give optimum satellite coverage to meet UK requirements and to overcome interference problems associated with receiving X-band data. It is located at West Freugh, near Stranraer, Wigtownshire, South West Scotland. In the future, it is planned that data will be received from other satellites.

NRSC and EODC

In addition to the West Freugh satellite ground station, the DRA also created the national Remote Sensing Centre (NRSC) and the Earth Observation Data Centre (EODC), now both under private ownership, and operates a photographic products facility in Farnborough.

The NRSC was created in 1980 to play an important part in achieving the British National Space Centre's (BNSC) goal of commercialising Earth observation. The EODC was established by the DRA to archive information from the ERS-1 satellite, process the data into geophysical products and distribute it to UK users. As well as being a UK national facility, the Centre is also an ESA Processing and Archiving Facility (PAF) responsible for distributing products more widely within the European user community. It will later be expanded to handle data from future missions such as ERS-2, Radarsat and the Columbus Polar Platform.

Image Data Facility

The Image Data Facility at Farnborough was created in 1982 in direct response to the real need for a dedicated photographic facility. The Facility provides a wide range of services to the remote sensing community on an operational basis.

Beyond SAR

Towards the end of the 1980s, ESA announced that they intended to consider a more advanced SAR than AMI as a core instrument to be flown on the first European Polar Platform mission,

BIS Visit

1933 1993

Royal Aircraft Establishment/Defence Research Agency

The Society is pleased to announce that, as part of its 60th Anniversary Celebrations, a visit for Society Members to the Royal Aircraft Establishment/Defence Research Agency at Farnborough, Hants has been arranged for 21 May 1993.

The visit will include a tour of facilities concerned with:

- *Remote Sensing Imagery Produciton (Optical & Radar)*
- *Radar Systems Research*
- *Power Systems Technology*
- *Electric Propulsion*
- *Chemical Propulsion*
- *Small Satellite Programme (STRV-1a and 1b)*
- *Measurements of Space Radiation Environment*
- *Space Test Facilities*
- *Complimentary Lunch and Refreshments will be Provided*

Registration forms and location maps are available from:
The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ

in Earth Observation

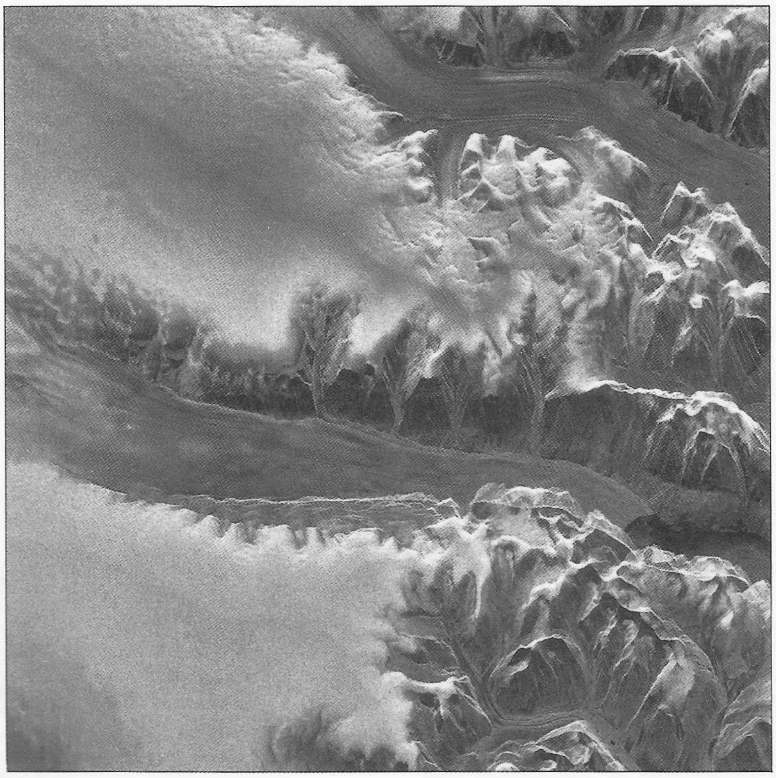
BY NICHOLAS THORNTON
DRA, Farnborough, Hants

now known as ENVISAT.

The Instrument conceived by the DRA, originally termed Versatile SAR (VSAR), uses more advanced antenna technology to provide several operating modes, the most important of which are a steered beam mode and a wide swath mode. In steered beam mode, any one of several available beams, covering different incidence angle ranges, may be selected to provide imagery of a relatively narrow (60 - 120 km wide) swath at a moderate (30 m) resolution. Alternatively, the wide swath mode may be selected to obtain imagery of an area 500 km wide. 100 m are required in image resolution. VSAR's flexible beam steering capability is achieved through a novel design based on active phased array antenna technology.

The VSAR instrument design was presented to ESA as a candidate for ENVISAT. Since then, ESA's scientific and technical establishment (ESTEC) have undertaken a detailed design study of a potential instrument which they have termed ASAR (Advanced Synthetic Aperture Radar) but which, with a few modifications, is essentially the VSAR design conceived in the UK.

The DRA's Space and Communications Department is continuing to contribute to the ASAR/VSAR programme by managing the breadboarding of an 'antenna tile' demonstrator. 'Antenna tiles' are a novel feature of the ASAR/VSAR design (the full antenna is built up from 20 such tiles, each independently powered) and the task of proving the basic technology is seen as an important step in the overall development programme.



An ERS-1 SAR image acquired on 6 October 1992 showing glaciation on the Greenland Coast, just one of the many applications of SAR data. The image was processed by the DRA's Image Data Facility from raw data transcribed at DRA West Freugh. *ESA*

Following the recent ESA decision to fly a Matra Marconi Space ASAR on ENVISAT, there is no doubt that the VSAR initiative has placed the UK in a strong position to compete for work in any future space SAR development programmes. One activity currently underway is a pre-feasibility study of a space SAR mission that could be flown as a follow-on to a Polar Platform SAR mission in the post-2000 era. This work is being carried out in collaboration with the French space agency CNES, and will involve consideration of several advanced SAR designs.

Nicholas Thornton is a member of the Business Development Office, Space & Communications Department at DRA Farnborough.

Impressive ERS-1 Imagery

BY CLIVE SIMPSON
Matra Marconi Space

The accompanying picture is a composite of images made on January 1 and 2 and March 28 1992, in different colours (here reproduced in black and white) and shows many interesting features.

The brightness of any radar reflection is influenced largely by the slope and roughness of the surface. Thus, the cliffs on the south-eastern side of the Isle of Wight show up brightly, while those on the western side are in shadow. Similarly, the eastern slopes of the South downs are brighter than the western ones.

Cities, towns and other man-made structures appear brightest because of the high incidence of corner reflectors. Also, because they remained stationary over the period during which the images were made they contribute equally to all three colours and thus appear white.

Roads are smooth and reflect most of the radar pulse away from the satellite - they appear as thin black lines. Railway lines, however, reflect the pulses well and appear white.

Heathland returns only some of the energy - trees, however, are good reflectors, so the New Forest - on the western side of the picture - shows up as a light mass surrounded by darker blocks of heath.

As the tidal current flows over the changing contours of the seabed its speed changes, producing short (two inch) ripples on the surface to which the radar is especially sensitive, so that a map of the bottom topography appears as a set of pale patches around the coast.

The wind and ebb tide, flowing past the Needles, combine to produce an intense choppiness.

Ships reflect well and appear as bright dots or crosses. Wakes persist long after a vessel's passage.

Matra Marconi Space, which has sites in Toulouse and Velizy, France, as well as Portsmouth, was responsible for the manufacture of some 55 per cent of the ERS-1 spacecraft.

ERS-1 SAR image of the Isle of Wight and surrounding area. *ESA/Matra Marconi Space*

Stonehenge from Space

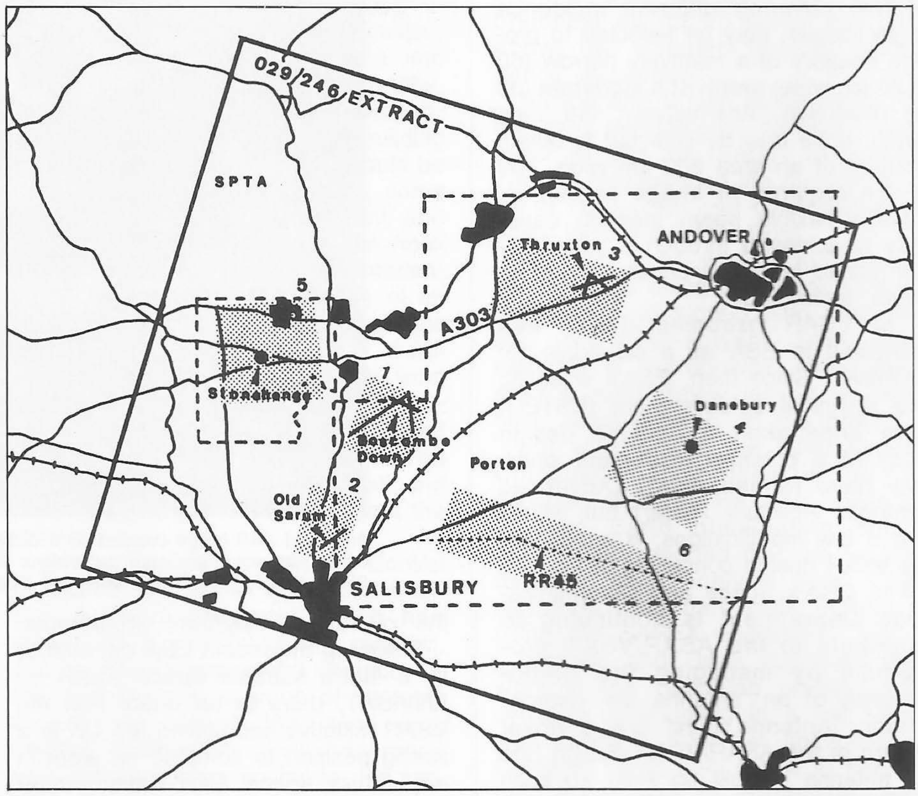
Over the past 10 years there has been a growing interest in the use of remote sensing satellites in the support of archaeological studies [1,2]. The US LANDSAT programme has been the main source of imagery for such studies and whilst very large features such as the pyramids at Giza can be discerned as shadow marks [3] and the course of portions of the Great Wall of China can be traced [4], the low ground resolution cell of the imagery (30-80 m) is such that the vast majority of archaeological features cannot be detected directly. However, by consideration of spectral, textural and structural indicators present on the imagery, areas can be identified that may contain sites of archaeological interest. The author, a Fellow of the Society, writes about the use of a SPOT panchromatic image of the Stonehenge-Danebury area of Southern England to assess the utility of high-resolution satellite imagery for archaeological studies.

BY DR M.J.F. FOWLER
Hants, UK

In the UK, as part of an archaeological survey of the North West wetlands, LANDSAT imagery, together with aerial photography, has been used to map areas of peat in the wetlands of Cumbria [5]. Satellite imagery having higher ground cell resolution than that provided by LANDSAT is now commercially available from a number of sources. Both digital imagery, such as that provided by the panchromatic and multispectral sensors of the SPOT satellite (10 m and 20 m resolution respectively), and photographic imagery, such as that obtained from the Metric Camera (20 m resolution) and the Large Format Camera (11 - 25 m resolution), are readily available [6]. In addition, one of the results of Perestroika in the former Soviet Union has been the availability in the West of high resolution (5 - 8 m) photographic imagery from the KFA-1000 and MK-4 cameras flown on Sojuzkarta satellites [7,8].

Compared with LANDSAT, little use has so far been made of the above high resolution imagery in archaeological studies. SPOT multispectral imagery has been indirectly applied in the preparation of bathymetric charts used in archaeological studies of an atoll in the Indian Ocean [9] and of part of the southern coast of Key Largo, Florida [10]. Of more direct application, SPOT imagery has been used in conjunction with a Geographic Information System (GIS) in the prediction of the locations of archaeological sites in a portion of the Arkansas River Valley in the USA [11]. A similar study integrating SPOT imagery with other geographical datasets through the use of a GIS is currently in progress as part of a study of settlement patterns in the Arroux River valley in Burgundy, France [12].

In an attempt to assess the usefulness of SPOT panchromatic imagery to archaeological studies in lowland Britain, a SPOT panchromatic image covering a portion of the Hampshire/Wiltshire border was purchased from the UK National Remote Sensing Centre Ltd with the intention of identifying the types of archaeological features that can be seen on the image.



Location of satellite image extract from Spot scene 029/246. The areas covered by the Stonehenge and Danebury survey areas are shown together with the locations of the image extracts 1-6.

The image comprised a photographic print of an extract from SPOT scene 029/246 recorded on 8 May 1987 and covered an area of approximately 32 by 27 km between Andover and Salisbury. The coverage was chosen in order to include two areas that had been well documented with respect to the presence of archaeological features: an area of some 25 by 20 km around the Danebury hillfort that had been mapped from aerial photographs [13] and an area of 5 by 5 km centred on the Stonehenge monument [14]. The satellite image was cloud free and covered approximately 90% of the Danebury survey area together with the whole of the Stonehenge survey area. The upstanding monuments that are present in the image area include long and round barrows from the Neolithic and Bronze Age, the Neolithic/Bronze Age Stonehenge complex and hillforts, enclosures and linear earthworks dating from the Iron Age. In addition to the upstanding monuments, there are also numerous archaeological features that are no longer upstanding but which have been identified on air photographs as crop or soil marks [13,14].

Man's influence on the landscape could be readily seen on the image with the landscape comprising a patchwork of fields together with built-up areas and linear features in the form of roads and railways. The runway patterns and taxiways of the airfields at Boscombe Down, Old Sarum and Thruxton were particularly conspicuous as well as the chalk spoil from construction work associated with the upgrading of the A303 road between Andover and Amesbury. This could be seen as a broad white linear feature extending over a distance of some 10 km. Uncultivated areas of chalk downland could also be identified most notably the MoD ranges at Porton and the eastern portion of the Salisbury Plain Training Area. On these areas, unmetalled tracks could be seen even though their width in many cases is significantly less than the resolving power of the sensor. The detection of these narrow tracks would appear to be due to a combination of the contrast between the exposed

chalk and the surrounding downland vegetation together with the linear nature of the tracks.

The identification of archaeological features on the image is still at an early stage. A consideration of the resolution of the panchromatic sensor and scale of the image suggests that many of the smaller features, such as the round barrows, may not be readily identifiable because of their being below the resolution of the sensor or because they are too small to be identified on the photographic print. From an initial interpretation of the image, it is clear that of the various upstanding features, only the site at Old Sarum appears to be directly visible on the image. This site has a long history, firstly as an Iron Age hill fort, and thereafter a Roman settlement, a Saxon burgh, a Norman motte, castle and town and the site of the first Salisbury Cathedral [15]. The features of the site that can be identified on the image include the circular earthworks together with the upstanding remains of the castle at the centre of the site.

Even though their earthworks may not be directly seen, several of the Iron Age hillforts and larger enclosures can also be identified from their characteristic shapes [13,14]. For example, the Danebury hillfort can be identified on the image as a circular feature that corresponds in dimensions to the upstanding earthworks. The ramparts of the hillfort are shrouded with trees which give the feature a characteristic "mottled" texture on the image.

The Stonehenge monument can also be identified on the image as a prominent circular feature, although the individual stones at the centre of the monument are smaller than the ground resolving cell of the sensor and cannot be discerned. The visible circu-

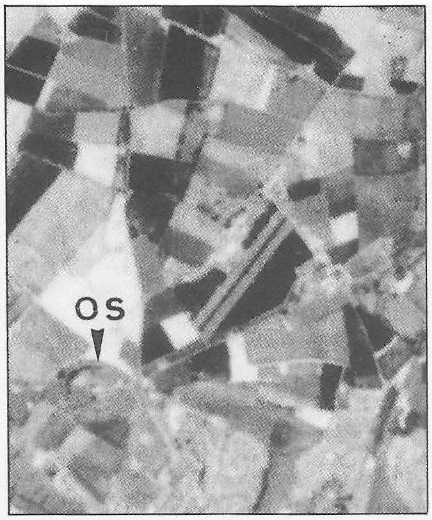
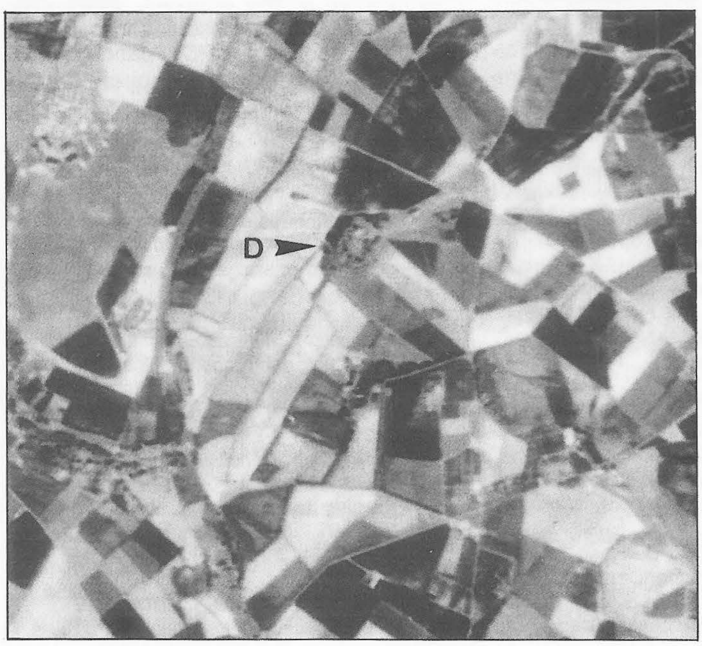
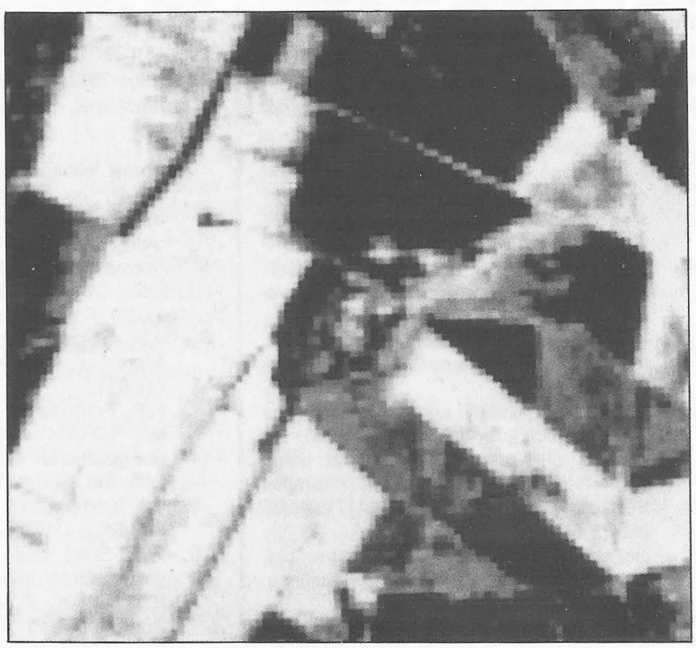


Image extracts 1-3: Recent man-made features visible on the Spot imagery. Clockwise from the top right, the airfields at Boscombe Down (extract 1), Old Sarum (extract 2) and Thruxton (extract 3). The archaeological site of Old Sarum (OS) can be seen on image extract 2 close to the southern end of the airfield runway. The chalk spoil associated with the improvement of the A303 road can be readily identified as a linear feature on image extract 3. *Imagery supplied by NRSC (c) CNES 1987*

Image extract 4: The Danebury hillfort (D) as seen by the Spot satellite. The ramparts of the circular hillfort are shrouded with trees giving the feature a "mottled" texture on the image. *Imagery supplied by NRSC (c) CNES 1987*





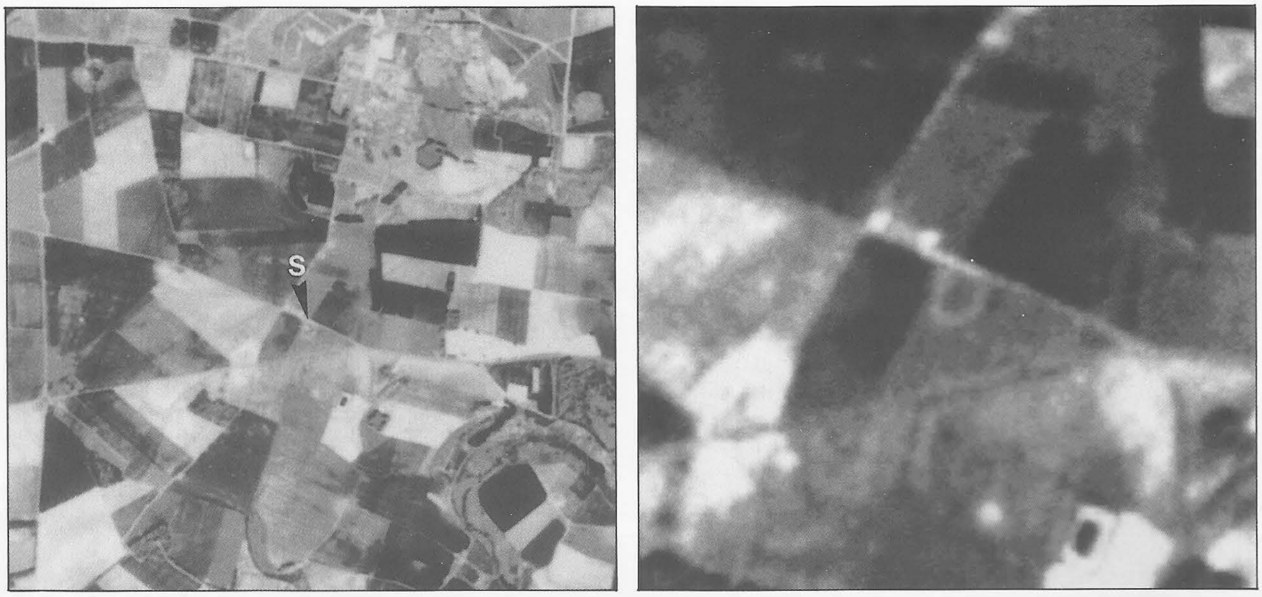


Image extract 5: The Stonehenge monument (S) as viewed from Spot. An approximately circular feature that partially encompasses the monument can be clearly seen on the enlargement of the extract together with the road and car park located to the North of the monument.
Imagery supplied by NRSC (c) CNES 1987

Image extract 6: The course of the Winchester to Old Sarum Roman road can be traced on this image extract as a linear feature having a dog-led at the western end. The linear feature is formed from a combination of a modern road and a series of field boundaries.*Imagery supplied by NRSC (c) CNES 1987*

lar feature appears to correspond to a footpath that partially encompasses the monument (clearly seen in air photograph in Figure 57 of reference 16) rather than the ditch of the henge monument itself.

The courses of some of the Roman roads in the area can also be seen on the image either as straight modern roads and railway lines or as a series of field boundaries forming distinct linear features. For example, the course of the Roman road from Winchester to Old Sarum (RR45) can be traced as a linear feature extending over several km with a dog-leg at its western end. Since high resolution satellite imagery can readily provide a "bird's eye" view of a large area on a single photographic print, which would otherwise require a mosaic of several conventional air photographs, such imagery could possibly be used in the identification of the courses of Roman and other ancient roads that have become fossilised in the landscape as modern roads and field boundaries.

The systematic analysis of the image is still on-going and it is hoped that additional archaeological features will be identified in due course. Upon completion of the analysis, some indication should be possible of the utility of high resolution SPOT panchromatic satellite imagery for archaeological studies in lowland Britain.

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Launch Report

First ORBCOMM in Orbit

An initial ORBCOMM satellite designed to demonstrate new commercial low-Earth orbit global mobile communications was launched as a secondary payload by the Pegasus rocket launcher on 9 February 1993. The spacecraft is expected to demonstrate two-way message and data communications capabilities around the world as a precursor to the ORBCOMM global communications network. The spacecraft will also provide an in-orbit platform for use in completing the hardware and software engineering required for the first two operational ORBCOMM satellites scheduled for launch later this year. (See p.135).

The spacecraft, which is about the size of a large briefcase and weighs 14.5 kg, is in a near-circular orbit approximately 750 km above the Earth in a plane inclined at 25 degrees to the Equator. ORBCOMM is scheduled to launch up to 26 more satellites using Pegasus. The first ORBCOMM satellite was designed and built by Orbital's Space Technology Laboratory in Boulder, Colorado. The Pegasus rocket was developed and produced by Orbital and its partner, Hercules Aerospace Company, and was used to place Brazil's SCD-1 environmental monitoring satellite, the primary mission payload, into orbit. (See Spaceflight, March 1993, p.89). ORBCOMM is a wholly-owned subsidiary of Orbital.

Ariane to Orbit New Intelsat VIII's

The first two Intelsat VIII satellites will be placed into geostationary transfer orbit in 1996 using Ariane 4, from the Kourou Space Center, French Guiana.

Intelsat 801 and 802 will be built by General Electric's Astro Space Division in Princeton, New Jersey. The satellites will have a liftoff mass of 3700 kg for a 16-year life service. They will carry 6 Ku-band and 38 C-band transponders and are designed to serve Intelsat users in the Pacific ocean region. They are the 13th and 14th contracts awarded to Ariane by Intelsat, the world's leading telecommunications operator. These two new contracts, together with four others recently awarded, require Arianespace to launch six large Intelsat satellites within the next three years starting October 1993.

The Arianespace backlog now stands at 36 satellites to be launched, worth French Francs 16.3 billion (approximately US$3 billion).

GE-1 Launch Contract

GE-1, the most powerful and advanced satellite design to date of GE American Communications (GE Americom) is to be put into orbit at the beginning of 1996 using an Ariane 4 from the Kourou Space Center, French Guiana.

Built by the Astro Space Division of General Electric, it will carry 24 C-band and 24 Ku-band transponders and will provide full Continental US coverage. GE-1 will serve broadcast, cable, education, government and private business.

SATELLITE DIGEST-251

Satellite Digest is our regular listing of world space launches. It is based upon a more detailed monthly satellite listing published by the Molniya Space Consultancy prepared by Phillip S. Clark.

Spacecraft	Int'l Desig.	Launch	Launch Site	Launch Vehicle	Mass kg	Orbital Epoch	Inclin. deg	Period min	Perigee km	Apogee km	Notes
Cosmos 2230	1993-001A	Jan 12.47	Plesetsk	Cosmos-B	825 ?	Jan 15.57	82.94	104.91	973	1,007	1
Molniya-1 85	1993-002A	Jan 13.08	Plesetsk	Molniya	1,600 ?	Jan 19.77	62.85	717.72	606	39,746	2
STS-54	1993-003A	Jan 13.58	KSC	Endeavour	93,000	Jan 13.85	28.47	90.89	304	333	3
TDRS 6	1993-003B	Jan 13.58			2,534	Jan 28.06	0.08	1,436.40	35,782	35,804	4
Cosmos 2231	1993-004A	Jan 19.62	Plesetsk	Soyuz	6,500 ?	Jan 24.08	67.13	90.06	179	376	5
Soyuz-TM 16	1993-005A	Jan 24.25	Tyuratam	Soyuz	7,150 ?	Jan 26.43	51.62	92.41	391	394	6
Cosmos 2232	1993-006A	Jan 26.66	Plesetsk	Molniya	1,900 ?	Jan 27.21	62.78	709.66	591	39,363	7

NOTES

1 Civil navigation satellite in the Tsikada series, co-planar with Cosmos 2181: given "Cosmos" name rather than "Nadezhda" since it does not carry the COSPAS-SARSAT transponders. Satellite is a cylinder, approximately 2 metres diameter and 2.1 metres long, plus a long boom for gravity stabilisation.

2 Communications satellite, co-planar with Molniya-1 78. Satellite has a cylindrical body, 1.6 metres diameter and 3.4 metres long plus six vanes of solar cells.

3 Carried six astronauts: J H Casper (commander), D R McMonagle (pilot), G J Harbought (mission specialist, MS-1, and extra-vehicular activity astronaut, EVA-1), M Runco (MS-2, EVA-2) and S J Helms (MS-3). Shuttle orbiter has a body diameter of 5.5 metres, body length 37 metres and wingspan 23.8 metres: mass quoted above is that projected for landing. Launched at 13.59 GMT, landed at Kennedy Space Center at 13.37 GMT.

4 Designated TDRS-F prior to launch, TDRS 6 in orbit: Tracking and Data Relay Satellite. Spacecraft hexagonal body about 6 metres high, two metres across plus two solar panels (span 17.4 metres) plus two dish antennae. Deployed from Endeavour about six and a quarter hours after shuttle launch. Mass quoted is that at launch, on station it is about 2,120 kg. Initially located over 210 °E, later to operate over 189 °E.

5 Fourth generation, close look photoreconnaissance satellite, replacing Cosmos 2220 which had been de-orbited the day before Cosmos 2231 was launched. Spacecraft will release some data return capsules during its mission, with the main re-entry cabin returning to Earth after about 60 days. No details of appearance, but probably with a maximum diameter of 2.5 metres and a length of 7 metres.

6 Two-manned spacecraft, carried cosmonauts G M Manakov (commander) and A F Polishchuk (flight engineer). Docked with Mir Orbital Complex using an androgynous docking system at the longitudinal port of the Kristall module (radially relative to the Mir core module) on Jan 26.31 (07.31 GMT). Cosmonauts due to remain in orbit until July 1993. Spacecraft is a cylinder with two vanes of solar panels + beehive + spheroid, maximum diameter 2.72 metres, cylindrical diameter 2.3 metres and length 7 metres. Actual launch time 05.58 GMT. Orbit quoted above is after docking with the Mir Orbital Complex.

7 Early warning satellite, probably replacing Cosmos 2097. Appearance of satellite is unknown, but possibly a cylinder 1.6 metres diameter and 3.4 metres long with six vanes of solar panels.

ADDITIONS AND UP-DATES

1983-046A	Cosmos 1463 decayed from orbit 1993 Jan 24.
1984-068A	Cosmos 1578 decayed from orbit 1993 Jan 10.
1992-077A	Cosmos 2220 was recovered approximately 1993 Jan 18.8.
1992-095A	Cosmos 2229 was recovered 1993 Jan 10.18: landing time quoted as 04.16 GMT in an ESA press release.

International Space Report

Orbital Transfer Contract

MCDONNELL DOUGLAS has been awarded a follow-on contract by the US Air Force to continue design studies of the Solar Electric Orbital Transfer Vehicle (SEOTV), bringing the total contract value to $697,000.

Under the contract awarded, McDonnell Douglas will continue design, requirements definition, and technology development of SEOTVs for medium launch vehicle application.

SEOTV is an alternative upper-stage concept that uses electric thrusters to transfer payloads into final orbit. By significantly reducing the amount of required fuel to perform the orbit transfer mission, the SEOTV reduces costs and enables the use of smaller launch vehicles to transfer satellites that currently require larger, more expensive boosters.

McDonnell Douglas is exploring the relative benefits of using expendable, integral and reusable SEOTVs. The upper stage is scheduled for initial operation at the turn of the century.

NASA 1994 Budget

NASA, Washington, DC - President Clinton's 1994 budget request for NASA will call for an increase over last year's budget with key provisions for the Space Station program and the development of important new technologies. The President has directed the Administrator to redesign the Space Station as part of a programme that is more efficient and effective and capable of producing greater returns on investment. The '94 package provides $2.3 billion for the smooth transition of the programme to a streamlined, cost-effective design, assuring stability in the programme during the transition and minimising any potential job losses. NASA is to work closely with the US Congress and international partners to maintain continuity in the programme. The new plan allows room in NASA's budget for future enhancements to ongoing agency efforts in aeronautics, human and robotic space flight and the transfer of technology to new and existing industries.

ESA Supports Follow-Up to HOTOL/Antonov Work

BRITISH AEROSPACE SPACE SYSTEMS, Stevenage, UK has been awarded a one year study worth 200kAU for a sub-orbital Rocket Ascent Demonstrator Mission (RADEM) by ESA's Space Transportation Directorate.

This study will look at a number of possible technology demonstration test vehicles for future reusable winged launch vehicle systems using an air-launched rocket vehicle and follows British Aerospace Space Systems' earlier work on the Antonov-225 launched HOTOL proposal.

As with the HOTOL/Antonov proposal, the task will be completed jointly with British, Russian and Ukrainian design teams - in this case the Molniya Design Bureau in Moscow (responsible for the Buran space shuttle), the Antonov Design Bureau in Kiev (responsible for the AN-225 heavy lift aircraft), and the Russian Central Aero- and Hydrodynamics Institute (TsAGI), based near Moscow.

As well as early (and low cost) flight demonstrations for future Advanced Launch Systems like HOTOL, the study is also intended to show how Western capabilities could be enhanced by collaboration with technology developed in Russia and the Ukraine. British Aerospace continues studies on Advanced Launch Vehicles for ESA in collaboration with Deutsche Aerospace though the ESA Winged Launcher Configuration Studies.

Inshore Waters from Space

MATRA MARCONI SPACE has been awarded a contract to develop a system for monitoring inshore waters and coastal environments using satellite Earth observation data. The initial study is being conducted under the British National Space Centre's (BNSC) civil Earth observation applications programme.

Some 22 such projects have been put out by BNSC, representing a wide range of interests in the use of satellite data. A short list (up to five) will be selected for phase two funding, to which BNSC will contribute 50 per cent. Industry is expected to identify resources for the balance.

The Matra Marconi Space proposal is to use data gathered by remote sensing spacecraft to provide information of value in the study of coastal waters. Satellites are ideal for monitoring the dynamic aspects of this type of environment. By concentrating on the coastal environment, where the need for information is particularly great (as a consequence of shipping density, navigation hazards, coastal erosion and pollution), the costs of satellite Earth observation can be spread among a variety of applications and users. The company's proposal will be known as MAICE (Management of the Inshore Coastal Environment).

Expansion at British Telecom Earth Station

GEC-MARCONI COMMUNICATIONS, Chelmsford UK, has supplied upgrading equipment for the BT Madley Earth Satellite Station in a record time of six weeks. Installation work was carried out on site by Marconi staff. Marconi has already supplied a large number of satellite communication equipments at both the Madley, Herefordshire and Goonhilly, Cornwall sites which are operated by BT.

Fast Rescue Beacon

DEUTSCHE AEROSPACE, Munich - The new Inmarsat-E distress radio call system provides a rapid alerting system. The Dornier-led Satellites and Application Systems Division of Deutsche Aerospace (Dasa/Munich) has developed this satellite-based distress call system.

The distress radio call system makes use of Inmarsat's worldwide and fully operational satellite system. Nearly 99.9% of commercial shipping traffic already operate within the coverage of the Inmarsat satellites which extends to 80 degrees latitude north and south. Twelve satellites deployed in four ocean regions currently ensure a totally reliable transmission.

The Soviet Venera Programme (Amendment)

The table on p.43 of the February 1993 issue of *Spaceflight* has now been revised by the author. The launch vehicle 8K78M did not come into use in 1963 but later, the first 8K78M/Venera launch being Venera-5 and not Cosmos-21.

Hand-Held Satellite Phones

INMARSAT, London has announced contracts with several major aerospace companies and consortia to help determine the best satellite for its proposed worldwide personal satellite telephone service, known as Inmarsat-P.

The three satellite constellations being considered for Inmarsat-P are geostationary (GSO); intermediate circular (ICO); and low-Earth orbit (LEO).

A geostationary satellite system would be a very powerful version of the systems that are used by Inmarsat and most other communications satellite operators now, with a few powerful and large satellites placed in orbit over the equator at an altitude of 36,000 km (22,300 miles) to provide global coverage.

An ICO system would require several satellites, possibly 12-15, moving in aligned orbital planes to provide global coverage. These satellites would be at approximately 10,000-15,000 km (6,200-9,400 miles) altitude and would appear to move slowly in the sky.

A LEO system would comprise even more, but relatively smaller satellites orbiting at approximately 1,800 km (1,125 miles).

This effort is aimed at assembling the remaining analysis and information necessary to enable Inmarsat's member-country investor organisations to make investment decisions on Inmarsat-P when its governing Council meets in July.

Canadian-Chinese Project

SPAR, Montreal, Quebec, Canada - The Spar Communications Group of Spar Aerospace Limited has announced a contract award worth over CAN$3.5M to supply a satellite communication network to the China National Petroleum Corporation (CNPC).

The network will operate on the Asiasat satellite and provide full mesh communications to 28 locations in China. It will bring voice, data, facsimile and video conferencing communications between CNPC oil sites, with the first sites expected to be operational in a few months.

Spar has been present in China for over 20 years, and CNPC is one of Spar's oldest customer. Spar's TDMA (Time Division Multiple Access) network using VSATPlus terminals was chosen over a traditional SCPC system because of its flexibility, its low cost expansion capability and superior reliability.

Israel to Produce ORBCOMM Communicators

ORBCOMM, Fairfax, Virginia - The Pegasus launcher is scheduled to launch the first two operational ORBCOMM satellites in late 1993, offering initial service in the United States. Three additional Pegasus boosters, each carrying eight ORBCOMM satellites, are scheduled to be launched in 1994, completing the 26-satellite system. (See Launch Report, p.133).

Through this constellation of 26 low-Earth orbiting small satellites, the ORBCOMM system will provide virtual full-time two-way global data communications. Customers will be able to send and receive short but vital messages using personal communicators for only a few cents each. These pocket-sized communicators will be priced between approximately $50 and $350 depending on their features, and will use lightweight, simple whip antennas. Potential ORBCOMM applications include emergency communications from remote places, communications of GPS-derived coordinates, remote asset monitoring, stolen automobile recovery and two-way "E-mail" communications for palm-top and lap-top computers.

Elsira is a leading electronics company in Israel, specialising in space, airborne, ground and naval electronic and communication systems. Tadiran, Elisra's parent company, is the largest electronics maufacturer in Israel, with sales of about $800 million. Elisra joins a growing list of leading electronic firms to sign agreements with ORBCOMM for the production and distribution of ORBCOMM communicators. The list includes Panasonic in Japan and Samsung in Korea. Elsira and other manufacturers are expected to submit proposals in response to ORBCOMM's Request for Quotation to purchase up to 5,000 communicators for delivery in late 1993 and 1994.

Canadian-Russian Project

SOVCAN STAR, Cambridge, Ontario, Canada has been selected by the Russian Ministry of Posts and Telecommunication and the Russian Space Agency as the first private satellite company granted the right to establish a commercial communication system for Russia.

This is the first time that members of the Canadian and Russian space industries have joined together to launch advanced communications satellites. The system will be based initially on five geostationary satellites and will offer telecommunications services to global users and will provide significant trade benefits to both countries. It is expected that Spar will be the satellites' prime contractor.

SOVCAN STAR Satellite Communications is a Russian-Canadian owned company formed in 1990 to draw together Russian and Canadian aerospace capabilities to provide commercial satellite communications. Russian and Canadian technical teams have worked together for more than two years examining the feasibility of launching a Canadian payload on a Russian spacecraft platform (or bus) using a Russian launch vehicle.

SOVCAN STAR's first international communications satellite is to be located over the Atlantic and is scheduled to be launched from Baikonur in 1996 using the Proton launch vehicle.

Ukrainian Cooperation

MATRA MARCONI SPACE - A protocol for negotiations has been reached with Ukrainian specialists that could lead to collaboration on a national satellite communications system for the Ukraine which was a key supporter of space programmes and projects in the former Soviet Union.

Part of the protocol agreement will involve Matra Marconi Space in studies of the communications requirements of the Ukraine to beyond the year 2000. The proposals include the Ukraine providing launching facilities, as well as manufacturing some systems and units for the spacecraft bus, and participating in the ground station network. Matra Marconi Space would contribute its payload manufacturing and ground station expertise.

BIS Visit

1933 1993

Royal Ordnance Rocket Motors Division Westcott

The Society is pleased to announce that, as part of its 60th Anniversary Celebrations, a visit for Society Members will be made to the Royal Ordnance Rocket Motors Division, Westcott, formerly the Rocket Propulsion Establishment on 14 July 1993.

The agenda for the day will include three briefings:

- *Background and History*
- *Site Operations*
- *Current Products and Markets*

Solid and Liquid Propellant Motor Firing Sites will be toured along with a visit to the Exhibition of Rocket Motor Hardware.

Complimentary Lunch and Refreshments will be provided. As there are a limited number of spaces available pre-registration is necessary.

Registration forms and location maps are available from:
The British Interplanetary Society
27/29 South Lambeth Road, London SW8 1SZ

BOOK NOTICES

These notices, compiled by L.J. Carter, are not intended to be reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

Full publication details are given for each book to enable copies to be ordered from a local bookseller, if desired. The address of each publisher also appears, for many items can now be ordered direct from them. If not, they will supply the address of a local agent who can handle matters.

First Light: The Search for the Edge of the Universe

R. Preston, Little Brown, 165 Great Dover Street, London, SE1 4YA, 1987, 263pp, £6.99.

This paperback relates the story of the Hale Telescope, housed on Mount Palomar in Southern California, since it was first opened in 1949.

It describes the telescope itself and how it has been used, e.g. in the search for quasars, as well as many of the astronomers who have observed there. The text is written in an informal style, almost as a novel, but is packed with interesting background information. It is just the ticket and excellent fare for a long winter evening.

History of Rocketry and Astronautics

J. L. Sloop, Univelt Inc., P.O. Box 28130, San Diego, California 92198, USA, 252pp, 1991, Hard Cover $60, Soft Cover $40.

This volume contains the proceedings of the 17th History Symposium of the International Academy of Astronautics held in Hungary in 1983. Early history is dealt with in a study of Korean Rockets and of Euler's importance to the aerospace sciences. The five papers which follow cover the development of liquid and solid propellant rockets to 1945 and include an account of the first 50 years of the British Interplanetary Society by Dr L.R. Shepherd and G.V.E. Thompson. Rocketry and astronautics after 1945 attracts a further seven papers while the final section, on pioneers of rocketry, features a biography of the late Dr Olgierd Wolczek, a former Fellow of the Society.

Properties of Galactic Carbon Stars

Z.K. Alksne, A. Karlovich & U.K. Dzervitis, Krieger Publishing Company, PO Box 9542, Melbourne, FL 32902-9542, USA, 1991, 172pp, $44.50.

This book examines the properties of those stars whose spectra are characterised by the presence of absorption bands of carbon compounds. Their properties can be explained by the unusual chemical composition of their atmospheres, a feature which shows them to be some of the most interesting objects in the late spectral classes and a group which is especially important in developing a theory of stellar evolution.

Carbon stars include objects which differ widely in temperature, luminosity, chemical composition and variability. There is also a sub-group of stars related to carbon stars, and possibly also to barium stars. The urgent need to classify them all systematically, though not yet undertaken, is quite important.

A characteristic feature of carbon stars, especially those in the later sub-classes and the "cold" Giants, is an observable change in their radiation, in other words, a variability. This seems to depend on the stage reached in stellar evolution but could equally be due to the mass of the star and other parameters. This makes it all the more important to find a way of explaining the physical properties and the processes which take place in the atmospheres of these stars.

At present it is difficult to determine the chemical content of the atmosphere of carbon stars not only because of their peculiar content but also because of the complexity of their spectra. However, with the collection of further data on basic properties, it will eventually become easier to sub-divide what is, at present, a spectrally inhomogeneous carbon star group.

Space Shuttle Almanac 1981-1991

J.W. Powell and L.R. Caldwell, Microgravity Press, 2351 Chicoutimi Dr., NW, Calgary, Alberta, Canada, 1992, 260pp, $29.95 USD ($39.95 Overseas Airmail).

Though not an encyclopedia, this almanac conveys a wide variety of Shuttle information in tabular form, illustrated with over 500 line drawings from NASA and Shuttle contractors. Detailed statistical information (e.g. vehicle weights and landing speeds) is presented for each mission, along with the dates of all pre-launch and post-landing events, ranging from vehicle stacking milestones to the ferry flights back to the launch site.

The book covers the first ten years of Shuttle flight operations. To keep it up-to-date, the authors plan to sell regular updates which can be inserted directly into the original volume, which has been produced by 'desk-top publishing' and is Cerlox bound.

The main body of the work falls into six categories:

1. 'The Orbiters', with drawings of all major Shuttle sub-systems and a detailed summary of the Enterprise test flight programme;
2. 'Mission Reports', which present an outline of each mission, including details such as seating arrangements, launch windows, mission durations, vehicle and payload weights, experiment and payload lists (with drawings) plus serial numbers for reusable hardware elements. All of the launch scrubs, countdown holds and landing diversions that occurred are documented;
3. 'Experiments', with designations, the experimenters and their affiliations for all primary, mid-deck, Student and Getaway Special (GAS) payloads, combined with lists of all DTO and DSO test objectives assigned to each mission, including military flights;
4. 'Propulsion', which includes detailed drawings of the main engines, solid rocket boosters, OMS pods and RCS thrusters plus ground test facilities and lists of ground test firings;
5. 'Mission Events', provides detailed official mission timelines (with deployments, EVA's, manoevures, etc.) along with diagrams of launch and landing profiles, the launch pads and landing facilities, plus floor plans of KSC launch processing facilities;
6. 'The Astronauts', which lists all the NASA astronauts and Shuttle Payload Specialists both past and present and chronicles changes in flight crew assignments during the programme.

The "How To" of Satellite Communications

Joseph N. Pelton, Design Publishers, 800 Siesta Way, Sonoma, Ca 95476, USA, 1991, $25.

In his new book the author continues to write in the same fluent and readable style of his previous books on Satellite Communications and their linkage to society. Here, however, he focuses less on the role of communications in an information hungry society to place emphasis on "how it is done" and brings considerable enlightenment to the reader about a subject that is often considered to be restricted to experts.

It also provides guidance for those embarking on a business venture in the satellite communications environment though the commercially astute will find the text useful only as a primer and will need to seek out many more facts, such as market demand, costs and risks, before going forward.

By its very nature, the book would not fully satisfy the practising engineer or student but - to be fair - this was not its intent. On the slightly negative side, the book is written almost entirely in one unorthodox large bold font which does not make for easy or speedy reading. It is also perhaps a slight overkill to dedicate 17% of the text to a glossary of terms. It would have been more useful to the reader to have shortened the list and provide more references, a feature which is missing.

Interestingly, Dr Pelton emphasises the role of VSAT's, particularly, in the rapid deregulatory European scene, an area of current popular interest, debate and uncertainty.

Spaceflight Attitude Dynamics and Control

V.A. Chobotov, Krieger Publishing Co., PO Box 9542, Melbourne, FL 32902-9542, USA, 1991, 150pp, $79.50.

This book is the outgrowth of many professional years spent in the field of spacecraft dynamics and orbital mechanics, as well as courses taught at the Aerospace Corporation, Northrop University and the UCLA Department of Engineering. It is useful both as a text-book for instruction at University level and as a reference work for engineers engaged in research, design and development in this field. It provides a comprehensive and self-contained treatment of the fundamentals of kinematics, rigid body dynamics, linear control theory, orbital environment effects and gives an introduction to the theory of the stability of motion.

Applications of theoretical developments are illustrated with numerous examples of actual spacecraft. Topics such as active nutation and damping, environmental effects and spin reaction control are all discussed and there is a good mix between theory and application.

An Appendix includes numerous exercises for students and teachers, with answers provided.

COMPUTER SOFTWARE

Dance of the Planets

Applied Research and Consulting Inc, PO Box 1955, Loveland, CO 80539, USA. The UK price £145 is not cheap but represents good value, since this is a quality product and "state of the art" for the PC. A sampler disc is available from ARC Inc. for evaluation before purchase.
System Requirements: IBM PC Compatible with 286, 386 or 486 Processor, DOS 3.X up, Hard Disc and EGA/VGA Display. Coprocessor Recommended. Mouse and Printer Supported.

Dance Of The Planets will convert a PC into a planetarium capable of showing animated views of all known planets and their moons and over 6000 asteroids and comets, against a background sky containing 10500 fixed stars and deep space objects.

It can be used to get a sky view from anywhere on Earth, an "Apollo view" of Earth from 250,000 miles up or a space view of the solar system from a distance of 250 AU, at any angle. Objects can be viewed for any time between 4,680 BC and AD 10,000, with magnifications between < 0.5X up to 32,000X. The attention to detail is impressive. For example, Earth, Mars, Jupiter and Neptune show rotating discs. At high magnifications, a view of Saturn reveals the phase of the disc, moving satellites, divisions in the rings, shepherd moons, shadows of the rings on the disc and the disc on the rings. Titan shows phases and the satellites undergo transits and eclipses. The orbital relationships can be studied. VGA screen colours approximate those seen from Earth.

A range of tools is provided. The pace of the simulation can be varied forwards or backwards up to 240,000 times faster than normal. Orbits, planetary grids, celestial and ecliptic grid lines can be shown. Objects can be located by name and labelled, planets can be tracked, screen images can be printed out with the local horizon. Simulations can be saved and resumed at a later date. There are on-line database access and help facilities.

The programme functions by constantly recomputing the gravitational forces between up to twenty objects and is claimed to achieve a positional accuracy better than 10 arc seconds for planets and 1 arc minute for asteroids. One can select one's own set of objects from the Dance database for simulation experiments. The manual provides plenty of experiments to try, e.g. one could go to Babylon in 136 BC to watch the solar eclipse, study natural comets and asteroids being perturbed or captured by Jupiter, examine orbital resonances or watch planetary motions in Earth's sky.

For this review, Dance was run on a 33Mhz 486DX PC with a VGA display and mouse. There were no obvious problems and the controls appeared easy to use. Most of the 153 page manual is given over to astronomy and detailed examples for the simulator. It is highly recommended to have a coprocessor fitted; the manual quotes typical speed improvements of 25 times.

Rendezvous in Space: The Science of Comets

J.C. Brandt and R.D. Chapman, Marston Book Services Ltd, PO Box 87, Oxford OX2 0DT, 304pp. 1992, £16.95.

The dramatic findings from the return of Halley's Comet in the mid-1980s forms the core of this "post-Halley" summary of cometary science, for the 1985-86 flyby was the matter of extensive scientific enquiry, using a fleet of spacecraft and technology unprecedented before in either power or sophistication.

The primary focus is on the modern era of comet research i.e. from 1950 onwards, including Fred Whipple's "dirty snowball" model of the comet nucleus. However, the book is not just about high-tech undertakings. It also describes the contributions by amateurs who have provided the majority of recorded comet sightings throughout history.

The book logically falls into two sections. The first provides an introduction to comets and considers their orbits, motions, nuclei and tails and the requirements for making observations.

The second concerns their origins. Full accounts are given of the studies of comets Giacobini-Zinner and Halley and projected future missions are described. Also included are a number of very useful appendices, including one on "How to calculate the positions of a comet".

Rocket Propulsion Elements: An Introduction to the Engineering of Rockets

G.P. Sutton, John Wiley & Sons Ltd., Baffins Lane, Chichester, West Sussex, PO19 1UD, 1992, 636pp, £56.

This sixth edition of this well-known text book covers such basic physical principles of rocket propulsion as nozzle thermodynamics, heat transfer, flight performance and propellant chemistry for all rocket types, including liquid, solid, hybrid, fuelled and electric propulsion systems.

Like its predecessors, it offers a thorough introduction to basic principles, a description of their physical mechanisms and designs and an understanding of how rocket propulsion is applied to various craft. As in past editions, it delivers both the theory and practical application information on rocket propulsion for guided missiles, space flight and satellite flight.

Also included are examinations of the latest changes in materials, system design, analytical simulations and manufacturing technologies. Seven new chapters and new illustrations have been added to cover subjects not in earlier editions e.g. advantages of liquid and solid propellant rockets, thrust vector control and electropropulsion. There is also new coverage on rocket exhaust plumes and a selection of rocket propulsion systems and safety issues.

Extragalactic Radio Sources - From Beams to Jets

J. Roland, H. Sol & G. Pelletier, Cambridge University Press, The Edinburgh Building, Shaftesbury Road Cambridge, CB2 2RU, 1992, 372pp, £40.

Some of the most interesting challenges of modern physics are those which concern active galactic nuclei, the origin of extragalactic jets and the formation of extended extragalactic radio sources.

Many new developments have proved possible as a result of improvements in data reduction techniques. These started to emerge in the early eighties and have since led to the production of spectacular radio maps of extended and compact radio sources. Other new fields of investigation, such as polarimetric and millimetric observations have also opened up. All these, together with high spatial, spectral and temporal resolutions possible in the X-ray, UV and optical ranges, have provided a wealth of new information on the physical conditions which exist in the cores of extra-galactic radio sources and in the inner regions of the jets.

This book contains the proceedings of a meeting which drew together both observers and theorists to discuss this rapidly-developing field and to obtain a comprehensive view of some of the problems involved. The matters considered - in about 60 papers - range from the reservoir of jet material around the central engine, those concerned with plasma and high-energy physics and recent observational data in the X-ray, optical and radio wavelengths. Special treatment is given to plasma physics problems concerned with particle acceleration, magnetic reconnection and beam plasma interaction coherent emission. A number of new theoretical developments are described, viz: concerning models to explain beam and jet formation.

Humans and Machines in Space: The Vision, the Challenge, The Payoff

Eds. Bradley Johnson, Gayle L May and Paula Korn, Univelt Inc., PO Box 28130, San Diego, California 92198, USA, 1992, 204pp, Hard Cover $50, Soft Cover $35.

This book, Volume 81 in the AAS Science and Technology series, contains the proceedings of the 29th Goddard Memorial Symposium held in Washington in May 1991.

Nineteen papers address the problems of living and working in space, including the interdependence of humans and machines though several speakers also drew attention to the effects of space development on Earth-bound institutions. Particularly important was the continuing development of space communications, which had not only improved the quality of life but reduced the constraining influence of former inflexible national boundaries. But even when the advantages and disadvantages have been set out and the cost argued at length, few will dispute that the root reason for space travel will be man's size and need to seek out and explore new worlds.

The late H.G. Wells put it in a nutshell when he described man's choice as "The Universe, or nothing".

Western European Military Space Policy

A. McLean, Dartmouth Publishing Co., Gower House, Croft Road, Aldershot, Hants, GU11 3HR, 1992, 186pp, £35.

Recent developments in the military use of space have led to reassessment of the question of whether Europe should continue to seek an autonomous military space capability. This will be an issue of continuing importance in the 1990s as a result of changes in perceptions of European defence and possible further developments in arms control. Besides European concerns over the possible deployment of weapons in space, continuing attention is being paid to the requirements for space-based surveillance systems able to monitor existing and future arms control agreements, especially those having major security implications for Europe.

All such matters raise the question as to whether Europe should continue to rely on US resources or if it should pursue a goal of complete autonomy. This book identifies and assesses the current situation regarding Europe's military posture in space against this background, analysing plans and intentions of Government and international agencies and suggesting how these can be carried forward to attain an acceptable security policy.

Clyde Tombaugh: Discoverer of the Planet Pluto

D.H. Levy, The University of Arizona Press, 1230 N Park Avenue, Suite 102, Tucson, Arizona 85719-4140, USA, 1992, $14.95.

This book traces the life of an astronomer, now in his 80s, who remains the only person to have discovered a major planet this century. As an amateur astronomer, Tombaugh gained the respect of his professional colleagues and went on to develop a career far beyond his famous discovery of Pluto.

For example, he even discovered comet 1931AN, but did not report this because it had been found on plates taken more than a year earlier and because it featured only the one observation: a minimum of three good positions are needed even for a rough preliminary orbit. As no more images could be found on other plates no announcement of a Comet Tombaugh was ever made.

This is among many other facets of a career which included further astronomical discoveries at the Lowell Observatory, rocket tracking at White Sands Proving Ground and planetary surveys at New Mexico State University. All are based on numerous interviews with Tombaugh, his family, friends and colleagues.

Astronomical Notebook

Ice on Mercury

Mercury, only 3,100 miles in diameter i.e. about one third of the size of the Earth, is the closest planet to the Sun. Temperatures on its equator can reach as high as 800 degrees Fahrenheit while its polar regions it might be as cold as minus 400 degrees.

Radar signals recently bounced off Mercury's surface have yielded results similar to those bounced off the icy surfaces of Jupiter's moons, so indicating that Mercury's polar regions, which are not tilted towards the Sun, never get heated, thus making it likely that ice caps exist there, perhaps as glaciers billions of years old.

Both hydrogen ad oxygen have been detected in the Mercurian atmosphere, with the breakdown of water vapour suggested as a possible source of hydrogen. Although no ice was detected by Mariner 10, which flew to Mercury in 1974 and 1975, the probe's images were imprecise and unable to cover the entire planetary surface.

The ice, if it is there, is most likely confined to polar regions permanently shadowed by rims of large craters or similar topographic features.

One theory is that the water was originally deposited when comets crashed on to Mercury's surface billions of years ago.

Gamma and X-Ray Satellite

The Spectrum-X and Gamma ray satellite, scheduled to be launched by Russia in mid-1995 with a 2-1/2 ton scientific payload aboard a Proton rocket, will feature the most powerful X-ray and gamma ray detector systems ever orbited.

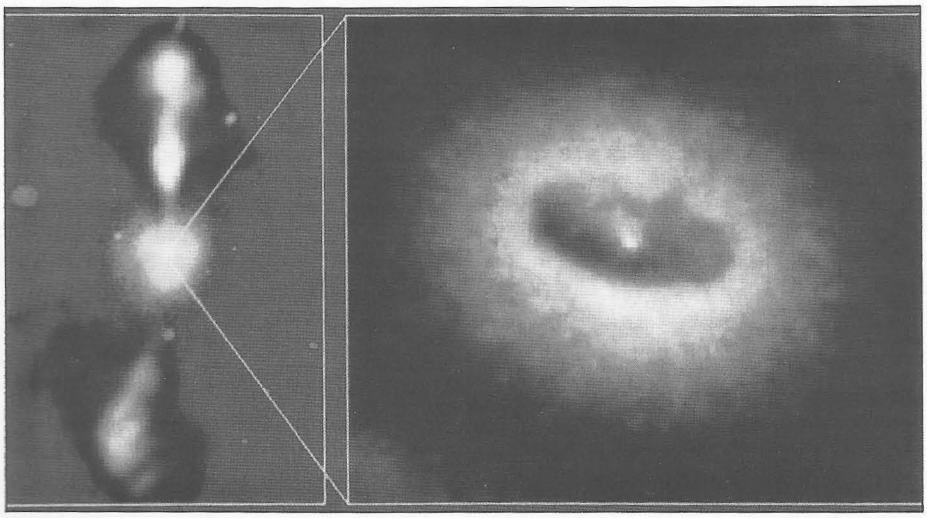
Lawrence Livermore National Laboratory, Columbia University, the Marshall Space Flight Center and two Italian research Institutes are to explore the characteristics of objects such as black holes,neutron stars and quasars.

The experiment, by agreement between NASA and the Russian Space Agency, is designed to measure the polarisation of X-rays; i.e. the degree to which their wave-like motions are lined up in a single plane.

Such measurements can help to understand whether an X-ray emitting region of space contains a black hole or how a rotating neutron star (a pulsar) emits X-rays.

Disc Fuelling a Possible Black Hole?

The disc of material at the core of a galaxy, NGC 4261, part of the Virgo Cluster 45 million light-years from Earth, may provide the best view yet of a possible black hole. The disc is tipped about 60 degrees, thus providing a clear view of the galaxy's bright hub.



(Left) Ground-Based Composite Optical/Radio View of Elliptical Galaxy NGC 4261 :
This giant elliptical galaxy is one of the 12 brightest galaxies in the Virgo Cluster, located 45 million light-years away. Photographed in visible light the galaxy appears as a fuzzy disk of hundreds of billions of stars. A radio image shows a pair of opposed jets emanating from the nucleus and spanning a distance of 88,000 light-years.*National Radio Astronomy Observatory, California Institute of Technology*

(Right) HST Image of The Core of NGC 4261:
A Hubble Space Telescope image of a giant disk of cold gas and dust fuelling a possible black hole at the core of the galaxy. Estimated to be 300 light-years across, the disk is tipped enough (about 60 degrees) to provide astronomers with a clear view of its bright hub, which presumably harbours the black hole.
The dark, dusty disk represents a cold outer region which extends inwards to an ultra hot accretion disk within a few hundred million miles of the suspected black hole. This disk feeds matter into the black hole, where gravity compresses and heats the material. Some hot gas squirts out from the black hole's near-vicinity to create the radio jets. The jets are aligned perpendicular to the disk, like an axel through a wheel. This provides strong circumstantial evidence for the existence of a black hole "central engine". *Walter Jaffe/Leiden Observatory, Holland Ford/JHU/STScI and NASA*

Black holes are still theoretical because their gravitational pull is so great that not even light can escape. Therefore, they cannot be seen. A black hole's existence can be detected by its gravitational influence on the motion of stars and other material near it.

NGC 4261 is unremarkable in visible light but observations with radio telescopes show a pair of opposed jets emanating from the nucleus and spanning a distance of 88,000 light-years. Spectroscopic data shows ionised gas in the nucleus moving at speeds approaching one percent of the speed of light.

The dark, dusty disc, 300 light-years across, represents a cold outer region which extends inwards to within a few hundred million miles of the suspected black hole. It feeds matter into the black hole, where gravity compresses and heats the material to tens of millions of degrees. Some hot gas squirts out from the black hole's vicinity like twin streams of water from a lawn sprinkler. The spin axis of the disc orients the radio jets. The cooler, outer regions of the washer-shaped disc confine the ionising radiation from the hot interior into a pair of cones whose axes are parallel to the radio jets.

Because dust and cool gas (neutral hydrogen) are not normally found in elliptical galaxies, the presence of a disc at all is a mystery. Much of the dust should have been destroyed quickly by the hot gas in the galaxy.

A possible explanation is that the dust is a remnant of a spiral galaxy swallowed earlier by NGC 4261.

"The nucleus is probably the home of a black hole with a mass 10 million times that of our Sun", said Dr Jaffe of the Leiden Observatory. "It is our best view to date of the immediate surrounding of the nucleus of an active galaxy", the name given to galaxies that emit especially strong radiation, so indicating that they harbour powerful energy sources.

Following the Space Shuttle servicing mission for Hubble in late 1993 spectroscopy will be used to study the motion of the gas in NGC 4261 within a few dozen light-years of the suspected black hole.

Planets in Creation

NASA's Hubble Space Telescope has uncovered the strongest evidence yet that many stars form planetary systems.

Dr C. Robert O'Dell of Rice University, Houston, Texas and colleagues have used Hubble to discover extended disks of dust around 15 newly formed stars in the Orion Nebula, a starbirth region 1,500 light-years away.

Such disks are a prerequisite for the formation of solar systems like our own.

"The disks are a missing link In our understanding of how planets like those In our Solar System form. Their discovery establishes that the basic material of planets exists around a large fraction of stars. It Is likely that many of these stars will have planetary systems".

Hubble Space Telescope's detailed images confirm more than a century of speculation, conjecture and theory about the genesis of a solar system.

According to current theories the dust contained within the disks eventually agglomerates to make planets. Our Solar System is considered a relic of just such a disk of dust that accompanies our Sun's birth 4.5 billion years ago.

Before the Hubble discovery, protoplanetary disks have been confirmed around only four stars: Beta Pictoris, Alpha Lyrae, Alpha Piscis Austrini, and Epsilon Eridani.

Unlike these previous observations, Hubble has now observed newly formed stars less than a million years old which are still contracting out of primordial gas.

Hubble images provide direct evidence that dust surrounding a newborn star has too much spin to be drawn into the collapsing star. Instead, the material spreads out into a broad, flattened disk.

These young disks signify an entirely new class of object uncovered in the universe, according to O'Dell. (He calls them Proplyds following the suggestion of his wife, Gail Sabanosh, who noted that for him protoplanetary disks was too much of a tongue twister).

Hubble can see the disks because they are illuminated by the hottest stars in the Orion Nebula and some of them are seen in silhouette against the bright nebula. However, some of these proplyds are bright enough to have been seen previously as stars by ground-based optical and radio telescopes. Their true nature was not recognised until the Hubble discovery.

Each proplyd appears as thick disk with a hole in the middle where the cool star is located. Radiation from nearby hot stars "boils off" material from the disk's surface at the rate of about one half the mass of our Earth per year. This material is then blown back Into a comet-like tail by a stellar "wind" of radiation and subatomic particles streaming from nearby hot stars.

Based on this erosion rate, O'Dell estimates that a proplyd's initial mass would be at least 15 times that of the giant planet Jupiter.

Many of the youngest and hottest stars in our Milky Way Galaxy are found in the Orion Nebula. The nebula is on the near edge of a giant molecular cloud which lies immediately behind the stars which trace the sword of the constellation of Orion the Hunter. The region of Orion studied intensely by O'Dell and collaborators is a bright part of the nebula where stars are being uncovered at the highest rate. These results suggest that nearly half of the 50 stars in this part of Orion have protoplanetary disks.

BIS Joint Event . . . Enrol Now !!

As a sequel to the TV programme 'Mars Alive' the Society and Birckbeck College, University of London, Centre for Extra-Mural studies (CEMS) announce a Two Day Weekend School organised by Dr R.L.S. Taylor and members of the CEMS Astronomy team.

Bringing Worlds to Life

to be held at

The Centre for Extra-Mural Studies, 26 Russell Square, London WC1B 5DQ
Saturday and Sunday, 15 and 16 May 1993
(To Mark the Occasion of the Diamond Jubilee of the Society)

***Programme and Speakers** (provisional)*

Day 1 *Chaired by L.J. Carter, British Interplanetary Society*

1. The Human Impact of the Earth's Environment.:
   Professor Andrew Goudie, University of Oxford.
2. Terrestrial Trends of Human Induced Changes in the Earth's Biospheric Environment:
   Professor I.G. Simmons, Universituy of Durham
3. The Nature and Resources of the Surface of Mars:
   Dr. Peter Catermole, University of Sheffield
4. Beyond the 'Horizon' of 'Mars Alive' - The International Research into Terraforming and Planetary Environmental Engineering:
   Peter Ceresole, BBC Horizon Science Producer.
5. Planetary Science Bases - Steps Towards Colonization:
   Dr R. Parkinson, British Aerospace.

Day 2 *Morning and Afternoon*

1. Terraforming Mars - The Warming - Biogeological Scenario.
   Video Taped Lecture Specially prepared for the Weekend School:
   Dr Christopher McKay, Ames Laboratory, NASA.
2. Methods of Inducing Planetary Change - Two Great Projects Mars & Venus:
   Martyn Fogg, Probability Research Group.
3. The Mars Atmosphere Problem - The Worldhouse Solution and Its Wider Applications:
   Dr R. Taylor, Birkbeck College, U.o.L.
4. Custom Built Planets - Move Over Slartybartfast!:
   Paul Birch, British Interplanetary Society
5. Summing Up the Present and Looking at Future Trends

Terraforming

The New Science of Planetary Environmental Engineering

The idea that other planets might be made habitable for humans and other forms of terrestrial life became a subject of serious scientific speculation and study more than 25 years ago. The word 'terraforming' describes this process of planetary transformation to one that is Earth-like in all important respects. Ideally a completely terraformed planet will possess a stable self-regulating ecosphere in which the prevailing conditions fall within the range of human physiological tolerance.

The study of how planetary environments can be re-engineered and changed and maintained as suitable for life - the study of terraforming - is something that is as important for the long term preservation of life on Earth as it is for the establishment of permanent human settlements away from our home planet.

Registration details, attendance fees etc are available from: Ms. Leslie Hannigan, Astronomy Desk, Centre for Extra-Mural Studies, 26 Russell Square, London WC1B 5DQ; Tel: 071-631 6627. As Accommodation Is Limited, Early Registration for this Exciting and Popular Study School Is Strongly Advised.

SPACE PROBE DIARY

Galileo

January 20

Galileo spacecraft is about 19.2 million miles (31 million km) from Earth and receding at more than a quarter of a million miles each day. It is 1.12 astronaomical units (104.3 miles) from the Sun, and has travelled almost 1.6 billion miles (2.6 billion km) since launch, or two-thirds of its total path to Jupiter.

The spacecraft is in the dual-spin mode, spinning at just over 3 rpm with the lower part fixed in orientation. It is transmitting coded telemetry at 1200 bits per second over the low-gain antenna. Except for the fact that the high-gain antenna remains undeployed, Galileo's health and performance are excellent.

On January 19 the flight team sent commands to pulse the antenna deploy motors 1800 times, concluding ten days of motor hammering this year. Counting the hammering session of December 29-30, 1992, a total of 13,320 pulses have been executed in the latest attempt to free the three stuck antenna ribs. Although there has been some motion in the deployment system and in the antenna, the ribs have not yet beed freed. The last remaining action in the plan for the stuck antenna is to spin up the spacecraft to 10 rpm in March but there is little expectation that this will help. The Project plans now to focus on doing the Galileo mission with the low-gain antenna.

The 4.8-metre (16-ft) diameter high-gain antenna, made of gold-plated molybdenum wire woven into a mesh, failed to open fully in April 1991. At best the low-gain antenna can only send back about one-hundredth as much data as the jammed antenna.

Without the main antenna, Galileo will not be able to send back detailed film of Jupiter's violent atmosphere and a much smaller number of still photographs.

Magellan

January 5

The Magellan spacecraft is operating normally, orbiting Venus 50 times each week and transmitting a carrier radio signal which is being precisely tracked by the Deep Space Network stations to extract gravity data.

Variations in the interior of Venus can be found by analysing the subtle changes in the Magellan orbit and comparing those with surface features. Unlike Earth, there is a strong correlation between the internal concentrations of mass at Venus and its surface topography.

Magellan arrived at Venus on August 10, 1990 and has completed 6,478 orbits, 842 orbits have been completed so far in its fourth 243-day cycle which ends on May 25, 1993.

February 8

The Magellan spacecraft continues to operate normally, transmitting a carrier signal plus 1200 bps X-Band telemetry. It has completed 6727 orbits of Venus, is 58% complete on its gravity data collection and now 105 days away from the start of the Transition Experiment.

Mars Observer

January 5

The Mars Observer spacecraft is being prepared for the outer cruise flight sequence. Adjustments to point the high-gain antenna directly at the Sun continued until January 6, 1993, at which time the antenna was powered to begin receiving and sending engineering and science data.

All spacecraft subsystems and instruments are performing well. The camera "bakeout" to prepare the instrument for operation will continue until January 14, followed by a focusing test on January 18. The spacecraft is now about 27 million miles (43 million km) from Earth, travelling at a speed of about 23,000 miles (36,000 km) per hour relative to Earth. Its heliocentric velocity is about 61,000 miles (97,000 km) per hour. One-way light time is approximately 128 seconds.

Pluto Mission

February 8

Proposals for two small space probes to study Pluto, the solar system's last known unexplored planet, have yet to receive funding or NASA approval as a full-fledged mission.

The cost would be about $600 million to $1 billion depending on whether the probes are launched by Russian or US rockets.

Pluto mission planners want to use two 362-pound, space probes, each measuring 4½ feet in diameter and 3½ feet high, carrying just four instruments each, including a tiny television camera. Launch would be around 1999, reaching Pluto between 2005 and 2007 and flying within 6,200 miles of the planet. Each probe would study one side of Pluto.

"Instead of sending another houseboat, we're sending very sophisticated desk-sized spacecraft," said Alan Stern, a planetary scientist at the Southwest Research Institute in San Antonio and chairman of one of two NASA advisory panels supporting the proposed mission. Voicing the other side, John Pike, space policy analyst for the Federation of American Scientists in Washington, said, "NASA has a process for selecting missions on the basis of scientific merit and Pluto was pretty far down on that list".

Pluto is usually the outermost planet though its long elliptical orbit sometimes brings it closer to the Sun than Neptune. This has been the case since 1979 but it will become the outermost planet again in 1999.

Pluto and Charon could turn out to be large ice dwarfs.

Ulysses

January 5

Spacecraft and science operations are performing well. Ground controllers are carrying out routine data-gathering activities and experiment reconfigurations. The 34-metre ground antennas are being used for ranging when the spacecraft is sending data at a low bit rate. Seventy-metre antenna ranging passes are also performed periodically.

Earth-pointing manoeuvres were carried out on December 27 and 30, 1992, and on January 3 1993.

Ulysses is now about 428 million miles (688 million km) from Earth, travelling at a heliocentric velocity of about 21,000 miles (32,000 km) per hour. It is about 15.5 degrees south of the ecliptic plane and slowly looping its way back toward the Sun.

January 10

Scientific highlights from Ulysses include the detection of interstellar pick-up hydrogen and oxygen ions; *in situ* measurements of the velocity (26 $\pm$ 2 km/s) and temperature (6700 $\pm$ 1500 K) of interstellar neutral helium, in excellent agreement with the UV measurements made by IUE, and the detection of six dust streams in highly inclined orbits beyond 5 astronomical units.

March 2

The Ulysses spacecraft is in a highly inclined solar orbit, now about 18 degrees south of the ecliptic plane, in transit from its Jupiter gravity assist in February 1992 toward its solar polar passages in 1994 and 1995.

Voyager

29 January

Voyager 1 is now 4.7 billion miles (7.6 billion km) from the Sun, heading outward. Voyager 2 is 3.6 billion miles (5.8 billion km) from the Sun and also heading outward. Both spacecraft were launched in late 1977 and use radioisotope-thermoelectric generators which were built in 1976 and which are still providing electric power nearly 17 years later. The two Voyagers along with Pioneers 10 and 11 are providing continuing data on the extremely distant composition of the solar wind. Radio signals from the four spacecraft are being used for part of gravitational studies of the mass of objects in the solar system.

Society News

With the half-way point of our Diamond Jubilee Year shortly to be reached we report on recent events and take a look at our forthcoming programme.

* * * Space '93 * * *

The 60th anniversary date of 13 October 1993 now draws nearer and with it the Society's special weekend event, **Space '93**. Details appear on p.137. A full and interesting programme has been arranged to celebrate this landmark in the Society's history. Please note the date 15-17 October and contact the Society for further information on the programme, accommodation and other arrangements.

* * * One-day Visits * * *

Nearer in time are our next one-day visits for members to view Space-related work as the guests of two well-known government establishments. Details are to be found on pp.128 and 135. Numbers are limited on both occasions and early pre-registration is necessary for security reasons. Both visits offer much of interest and should be well worthwhile.

* * * Bringing Worlds to Life * * *

The above heading is the subject of a Two-Day Weekend School which the Society will be holding jointly with the Centre for Extra-Mural Studies, Birkbeck College, University of London on 15-16 May 1993. The programme has the theme 'Terraforming', the New Science of Planetary Environmental Engineering, and it takes up in greater depth many of the points of the recent TV 'Horizon' documentary entitled 'Mars Alive' in which the Society's work was featured. Not surprisingly, many of the speakers at this event are those who were associated with the documentary. Please see p.140 for programme and registration details.

Radio and TV Programmes on Terraforming

The Society has been involved in the preparation and production of the following:

A radio programme in the science series 'A Step Beyond' to be broadcast on Radio 4 at 7:20 pm on April 8; the TV programme in the 'Horizon' series, entitled 'Mars Alive' which is to be repeated towards the end of the series and again during the summer repeats. (Dates and times have not yet been announced).

60th Anniversary on Radio

David S.F. Portree, Fellow of the Society, writes to us saying:

I wanted to let you know that I have recently sold a script to STAR DATE, the syndicated astronomy and spaceflight radio series, which is called the "The BIS is 60". It should be on the air in October, In time for the anniversary. STAR DATE Is heard by some 10 million people each week, from over 200 radio stations in the United States, Canada, Guam, Germany (beginning March 1), and, possibly by October Saudi Arabia.

Special 60th Anniversary Cele

The following reports on recent events have been provided by Fellows of the Society:

'Mars Alive'

Report By Dr R.L.S. Taylor

Screened on BBC 2 on Monday 8 February 1993 the Horizon programme 'Mars Alive' was something of a landmark in the presentation of space science on television. Made at the Instigation of a Fellow of the BIS the subject was itself an unusually adventurous one - terraforming Mars. Produced and scripted by Peter Ceresole and researched by Rosita Sherrard, the programme was both visually spectacular and scientifically and technically right up to date. For example film of the Russian space-mirror, that been tested in orbit only a week before the Horizon programme was shown, had been incorporated into the script not just as a novelty but in the correct scientific context.

Many of the leading scientific personalities investigating the frontiers of planetary environments gave their views on how the terraforming of Mars might best be brought about. The work in the USA was well covered by Chris McKay, NASA, Ames Laboratory, (himself a member of BIS), Robert Zubrin, Martin Marietta Corporation, atmospheric physicist Jim Kasting of Pennsylvania State University, and geologist Michael Carr who is widely regarded as perhaps the leading authority on the geophysical nature of the surface of Mars.

Previously largely unknown in the West the extensive Russian research into completely closed biosystems, such as Bios 3, in which astronauts had remained isolated from the outside environment successfully for six months, was described by Professor Josef Gitelson. Disarmingly simple but elegant experiments designed to make it possible to mathematically model closed bio-feedback systems were also shown and explained by Professor Nikolai Pechurkin.

British research was represented by Martyn Fogg of the Probability Research Group, Paul Birch a former astronomer and a well know researcher on advanced space technology and science, and Richard Taylor of the Centre for Extra-Mural Studies, Birkbeck College. All three of the UK scientists are Fellows of the BIS, and the distinct contributions made by their work demonstrate that even in a country where financial support for space science and technology ranges from little to none it is still possible for British scientists to make a major input into a new and rapidly developing area of science.

The studies done by the Japanese company Ohbayashi of how to construct a 'Mars City' - a colony of 150 persons - early in the 21st Century were described by Dr. Yoji Ishikawa. The colony was intended to be self-sufficient and was seen as the preliminary step along the path to a completely terraformed Mars. Dr Ishikawa hoped that the first human baby might be born on Mars in 2057 exactly 100 years after Yuri Gagarin first orbited the Earth.

The scientific content of the programme was broad and well presented and it successfully brought out the underlying similarities of what at first appeared to be quite different approaches to the problem of terraforming Mars ranging from the optimistic CFC warming biogeophysical scenario, through the high energy release of volatiles to produce a dense atmosphere, to an engineering scenario of roofing a major part of the planet. The fact that terraforming is now truly an area of scientific study and not science fiction was made clear by the fact that no one made any gung-ho proposals to overcome the difficulties of making Mars habitable. All the scenarios on offer capable of making Mars suit-

Year Programme

bration at SPACE '93

able for humans and other terrestrial biota were conceived as being done entirely within the available resources and constraints of the planet's natural endowment of resources.

What had to remain unsaid In Horizon's 50 minutes was that the subject of terraforming is not just concerned with Mars but is properly the study of how planetary environments are established and how they can be changed or upset either deliberately or accidently. We forget at our peril that mankind Is already unconsciously terraforming the Earth. Studying how the conditions of Inherently simpler systems than the Earth might be changed, Mars for example, can only increase our ability to understand the only world that we know for sure supports life - our own planet.

Illustrated with stunning computer graphics and specially built models, 'Mars Alive' is to be repeated later in the year. If you did not see the first showing make a point of seeing it next time around. It is particularly satisfying that such a forward looking programme on space science and technology should have been made and shown In our Diamond Jubilee Year featuring the BIS offices and the work of at least four members of the Society! The BBC are to be congratulated on an excellent programme.

Nuclear Power for Deep Space Missions?

F.J. Gardner and Dr A. Stevens,
Rolls Royce and Associates Ltd.

Evening lecture, 3 February 1993
Report by Mr G.R. Richards

The evening lecture at BIS HQ on 3 February 1993 was given by Mr F.J. Gardner of Rolls-Royce, who has been involved in nuclear reactor design for many years and was a founder member of the UK Space Reactor Group. He gave a detailed and highly informative survey of the history and technical features of the various space nuclear power programmes of the past and ended with a survey of current technology and a look at possible applications.

After a brief mention of the radioisotope type of power source used in deep space probes such as Galileo, he turned to his main subject of fission reactors. Compared with radioisotope generators, these offer the advantage of much higher potential power levels. Their history dates back to the mid 1950s, when the USA initiated the SNAP programme to develop nuclear power sources for space use. The first device built, SNAP 2, set many of the design features for later reactors. The uranium fuel was cooled by sodium/potassium liquid metal pumped electromagnetically through the core. The core was surrounded by a beryllium neutron reflector and the reaction was controlled by opening windows in the reflector. The device was never flown, but a development, the SNAP 10, was successfully launched in 1965. This was also typical of later designs in that it was mounted on a radiation shield and the support equipment, thermoelectric converters, conical thermal radiator and the rest of the spacecraft were all placed in the shadow of the shield. SNAP 10 produced 600 watts for six weeks before It shut down due to a fault In the supporting spacecraft. Later SNAP designs were developed with much higher power levels and Rankine-cycle turbine systems, but these were never flown.

Mr Gardner then described US work on nuclear propulsion. The NERVA programme developed a series of rocket motors in which hydrogen propellant was raised to high temperatures, typically 2500 K, by passing it through the core of a nuclear reactor. Run times of over an hour at power levels over 1000 MW were achieved in ground tests, demonstrating a specific impulse of twice that of the best chemical rockets. One design, the Phoebus, developed 4000 MW.

NERVA was cancelled In the post-Apollo run-down of the US space programme. The late 1970s saw very little US activity, though the USSR was regularly launching nuclear reactors to power radar reconnaissance satellites. However, a device called SPAR was designed at Los Alamos in this period. This was unusual In featuring heat pipes rather than pumped fluid for cooling the core. More funding was provided In the 1980s, when the Departments of Energy ad Defense, together with NASA, Initiated the SP-100 programmes. This had the objective of developing a device with a mass under 3 tonnes to provide 100 kW of electrical power for seven years. The current design has a fast reactor with a uranium nitride core cooled by lithium. Thermoelectric devices convert the heat to electricity and the radiator uses potassium heat pipes. The technology is now ready for application and a generator could be launched in this decade.

An alternative approach to power conversion uses thermionic devices that are incorporated in the fuel rods themselves. This was studied but rejected in the SP-100 programmes, but the USSR went ahead with a thermionic generator called Topaz. Two Topaz generators were successfully launched in 1987. US interest in thermionic generators has led to the purchase of a Topaz-type device from the Russians. This is being ground-tested at the Sandia National laboratory and a flight test is planned.

The Earth-Space Environment

Symposium held at BIS Headquarters, London,
25-26 November 1992
Report by Dr Dave G. Fearn, DRA, Farnborough.

The complex and severe environment encountered beyond the Earth's atmosphere must be taken into account by those with an active interest in designing, building or using spacecraft of any type. The subject was superbly treated by a series of recognised authorities In their respective fields at this two-day symposium.

Following an Introduction by Dr Dyer, in which he mentioned that the meeting was being held in a year which included the 80th anniversary of the discovery of cosmic rays and the 100th anniversary of the birth of Compton, Dr Desmond King-Hele commenced the proceedings with a historical account of how the present understanding of the upper atmosphere has developed. He went back to Aristotle's early concept of "Celestial Spheres" of fire, air, water and earth, which ruled supreme until the beginning of the modern scientific era. The contributions of Boyle, Halley and Erasmus Darwin to the development of atmospheric models were mentioned, as were the later theories of Sir James Jeans, Chapman and Milne, and others.

The dawn of the space age gave exciting new opportunities to study the outer reaches of the atmosphere, and these were grasped enthusiastically and effectively by Dr King-Hele's group at RAE Farnborough, amongst others. As a result there is now a much better understanding of the atmosphere and of its variability.

Atmospheric effects on spacecraft and on space debris were then discussed by Dr Richard Crowther of DRA Farnborough. He pointed out that of more than 7000 catalogued objects in orbit around the Earth, only about 6% are operating spacecraft. In addition to these objects, there are more than 70,000 uncatalogued ones greater than 1 cm in size,

and a huge number of smaller items of debris. These pose a growing hazard to future space activities, especially in certain orbits. At present, only the natural processes of orbit decay can reduce this problem, and these are effective only at the lower altitudes.

Prof Tony McDonnell of the University of Kent continued this theme and Included the natural hazards due to the meteoroid environment. He quoted in his talk much up-to-date Information derived from analyses of the large number of Impact craters on the LDEF spacecraft, which was returned to Earth by the Shuttle following 5½ years in low orbit. This aspect was then expanded upon by Simon Green, also of the University of Kent, who compared the man-made and natural environments, and made reference to some of the many questions which remain unanswered. One of the problems posed by the tenuous outer atmosphere concerns the erosion of spacecraft surfaces by atomic oxygen, which is the dominant atmospheric constituent up to about 500 km altitude. The phenomena involved were described by Dr Steve Gabriel of the University of Southampton, who also covered the many methods of experimental simulation developed in laboratories around the world. The one at Southampton makes use of arcjet technology. The University is also intending to measure erosion effects in orbit by means of an experiment to be flown on the DRA's STRV-1a spacecraft.

The next speaker, Dr Tony Martin of the Culham Laboratory, moved further into space, when he considered the complex interaction between orbiting spacecraft and the ambient plasmas with Debye lengths varying from millimetres at low altitude to metres at geostationary orbit and beyond. Factors to be considered include the Earth's magnetic field, the injection of high energy particles into the polar regions, and the high velocity of a typical spacecraft.

One result considered by Dr Martin was spacecraft charging. This was amplified in some detail by Dr Andrew Sims, of DRA Farnborough, who commenced his talk by describing some of the spacecraft operational anomalies attributed to this effect. He then covered some of the experimental measurements made in orbit of the charging phenomena of concern.

Dr Martin concluded a fascinating first day by describing the interactions that can take place between solar arrays and the ambient space plasma. He covered in particular the effects to be expected when using a moderately high voltage, such as the 160 V planned for the Space Station. The polarity of the Station with respect to the array has a major influence on the plasma current flowing and on sputtering damage, amongst other effects, and must be very carefully considered during the design process.

The second day commenced with a comprehensive picture of the Earth's radiation belts, provided by Eamon Ealy of ESTEC, which included very recent data from spacecraft such as CRRES, launched in 1989. Reference was also made to the inadequacy of the models of the radiation belts currently available.

Dr Dyer then returned to examine the much higher energy particles present in cosmic rays, which are now thought to originate in supernovae, as well as from the Sun and Jupiter, also via interstellar acceleration processes. These particles can cause serious problems in microelectronic components, including single-event upsets and latch-ups. His group is very active in this field, and he described experiments flown on Concorde, the Shuttle, UOSAT-3, GRO and, in the future, STRV-1a.

The Sun's influence was expanded upon by Joe Hirman of SESC, who provided a wealth of information, including data from major solar flares which occurred as recently as 30 October and 2 November 1992. As an example of the variability of solar activity, these events gave X-ray flux increases of 2 orders of magnitude, and an increase in the proton flux of 3 orders. Dr Gabriel then went into more detail concerning such events, and referred to attempts being made to model them.

The scene then moved further outwards to consider the solar wind and its complex interactions with the Earth's magnetic field. This topic was dealt with by Dr Alan Johnstone of MSSL. He presented a fascinating account of the interactions, with reference to data from many recent spacecraft, including Giotto, CRRES, Ulysses and AMPTE. The influence of the solar wind on the observation of extragalactic radio sources was then covered by Dr Vivien Moore of Imperial College, with particular reference to the Cambridge Interplanetary Scintillation Array. Using these techniques, it is possible to map variations in solar wind parameters, including out of the ecliptic plane.

The final paper concerned the effects of weightlessness on astronauts. It was given by Richard Taylor of Birkbeck College, and covered all relevant bodily parts and functions. Mineral loss from the bones appears to be a dominating influence, and it is currently postulated that this is a result of the lack of gravitational forces; a bone that is not stressed is likely to lose essential minerals, primarily calcium and phosphorus.

The Symposium concluded with a well-attended round-table discussion covering each topic in turn. The main conclusions were, as might be expected, that more experimental data are needed, improved theoretical models must be developed, and additional funding is required, for both laboratory work and experiments in space. Technical issues addressed included the desirability of the use of electric propulsion to de-orbit all spacecraft, the concern about the in-orbit storage of used nuclear reactors, and the desirability of predicting solar disturbances, possibly by locating suitable spacecraft at a Lagrange point in the solar wind upstream of the Earth. As regards manned space flight, the discussion centred on the long-term effects of weightlessness and cosmic rays.

Acknowledgements

The organisers of the Earth-Space Environment symposium, Dr Clive Dyer and Dr Gordon Wrenn of the Defence Research Agency, Farnborough, are to be congratulated on bringing together such an impressive body of speakers to impart their knowledge to a large and appreciative audience, and on devising an absorbing and logical programme. To complement this technical excellence, the accommodation and catering were also of very high standard, as expected of a meeting hosted by the BIS.

* * *

SOCIETY MEETINGS DIARY

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.

It may occasionally happen that, for reasons outside its control, the Society has to change the dates or topics of meetings. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always recheck the scheduled meetings in the latest issue.

7 April 1993 — 7 pm - 8.30 pm

Cassini

Mr C. Cochrane

Cassini is a project planned by ESA and NASA for a spacecraft to survey the planet Saturn and its environs. During the journey to Saturn, fly-bys and investigations will by made of asteroids and Jupiter. After arrival at Saturn the spacecraft will orbit the planet for a further four years, using remote sensing to examine its satellites, rings and the planet itself. A sophisticated probe will be released in the first orbit to land on the mysterious moon Titan, to explore its atmosphere and surface.

The presentation will describe the scientific objectives of the mission, its trajectories and explain the engineering problems of the Titan Atmosphere Probe, concluding with a review the feasibility of the proposed solutions and present the innovative features of this fascinating mission.

5 May 1993 — 7 pm - 8.30 pm

Results from ERS-1

Dr G.E. Keyte
DRA Farnborough

The European Space Agency's ERS-1 satellite was one of the most complex remote sensing satellites ever launched. Despite its complexity, it has functioned almost perfectly since launch in 1991 and has enabled a wide range of research and application projects to be undertaken.

This paper briefly describes the main characteristics of the ERS-1 instruments and gives an account of their 'history' since launch. Some of the main results obtained from each of its instruments are reviewed, covering both the two microwave instruments (the Active Microwave Instrument and the Altimeter) as well as the instrument provided by the UK, the infra-red radiometer (ATSR). It will conclude by reviewing the future development of microwave remote sensing satellites after ERS-1.

14 August 1993

48th Annual General Meeting

The 48th Annual General Meeting of the Society will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, on Saturday, August 14, 1993 at 12 noon. Details of the Agenda will be published in due course.

Admission is by ticket, available to Corporate Members (i.e. Fellows of the Society) only, who should apply in good time enclosing a stamped addressed envelope.

Council nomination forms are obtainable from the Executive Secretary. These must be completed and returned not later than 12 noon on May 22, 1993. If the number of nominations exceeds the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all Corporate Members.

6 October 1993 — 7 pm - 8.30 pm

Microsatellites on Micro-budgets

Prof. M N Sweeting

The prohibitively high cost of space projects has effectively restricted first-hand access to space to a handful of nations and international agencies. Spacecraft have grown ever larger and more complex and are also taking longer time-scales from concept to orbital operation. Advances in VLSI microelectronics have catalysed a new species of small, low-cost yet sophisticated and highly capable 'microsatellites' - complementing, and sometimes providing an alternative to, high-cost traditional satellites

The lecture describes the University of Surrey UoSAT microsatellite programme which reviews the key technologies, management techniques and potential applications of small satellites.

SYMPOSIA & CONFERENCES

19 May 1993 — 10 am - 5.15 pm

Electric Propulsion of Spacecraft

This is the latest in a series of technical Symposia of particular interest to UK participants recording important developments in space technology.

The Programme includes: European Electric Propulsion Survey: The Artemis Spacecraft and Mission: Nuclear Electric Propulsion: The UK-10 Ion Propulsion System: The RIT-10 Ion Propulsion System: The UK-25 Ion Thruster: The RIT-35 Ion Thruster.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Advance Registration is necessary.

Registration: Forms are available from the Executive Secretary. Please enclose a sae.

12 June 1993 — 10 am - 4.30 pm

Soviet Astronautics

The symposium is in its 13th year as an event which reviews the space programme of the former Soviet Union. The programme for 1993 will include talks on the following topics: The Biosputnik programme up to 1993; USA-Russian Manned Cooperation 1992-1995: update on the Manned Operations on Mir; Obscure Unmanned Soviet Satellite Missions, and others still to be decided. A Film will be shown including clips never seen before in the UK. There will be opportunities to ask questions of some of the leading experts on the Soviet Space Programme in the West.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Advance Registration is necessary.

Registration: Forms are available from the Executive Secretary. Please enclose a sae.

22 September 1993 — 10 am - 4.30 pm

European Rocketry in the 1930's

As part of the Society's Anniversary Year the History Working Group are holding a Symposium on European Rocketry in the 30's. Contributions have been invited from Germany, France, Russia and the UK. The 30's is seen as a particularly interesting decade in that much theoretical and practical work was undertaken that laid solid foundations for later projects.

Whilst much publicity has surrounded the experimental and theoretical work carried out in Germany an enormous amount was also carried out elsewhere, particularly in Russia. Much of this story has yet to be told.

Advance Registration is necessary.

Registration: Forms are available from the Executive Secretary. Please enclose a sae.

15 - 17 October 1993

SPACE '93: Space Initiatives

This Special Society two-day meeting to commemorate the Society's Diamond Jubilee, 1933 - 1993 will include updated versions of many of the papers originally scheduled for Space '92 but which were carried forward when Space '92 had to be deferred owing to the reduced support arising from the current widespread recession.

The main Technical Sessions will consider past, present and future initiatives in space exploration.

Advance Registration is necessary.

Details of the Programme and Registration Forms will be available from the Society in due course.

VISITS

21 May 1993

Royal Aircraft Establishment/Defence Research Agency

(Farnborough, Hants)

A one-day visit with briefing and tour open to a limited number of members interested in remote sensing, advanced propulsion systems etc.

Pre-registration is necessary. Details of Programme and Registration forms are available from HQ on request. (See p. 128).

14 July 1993

Royal Ordnance Rocket Motors Division Westcott

A one-day visit to Royal Ordnance Rocket Motors Division Westcott, formerly the Rocket Propulsion Establishment. The agenda for the day will include three briefings:

- Background and history
- Site operations
- Current products and markets

Solid and liquid propellant motor firing sites will be toured along with a visit to the Exhibition of Rocket Motor Hardware.

Pre-registration is necessary as limited number of spaces available. Registration forms are available from HQ on request. (See p. 135).

LIBRARY

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. Membership cards must be produced.

2 WAYNE

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Spaceflight

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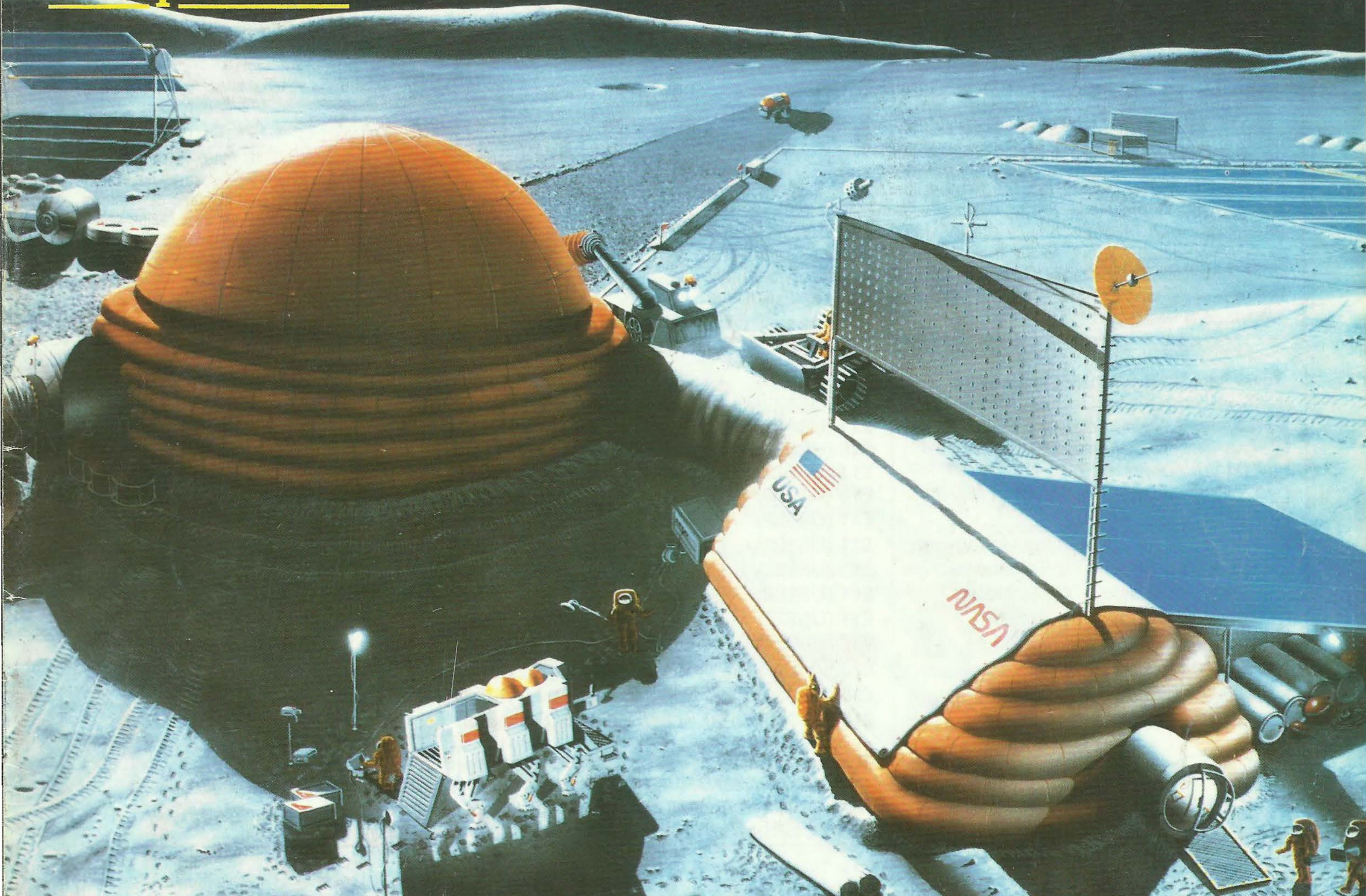

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NEW TITLES

Apollo 8: Go For TLI

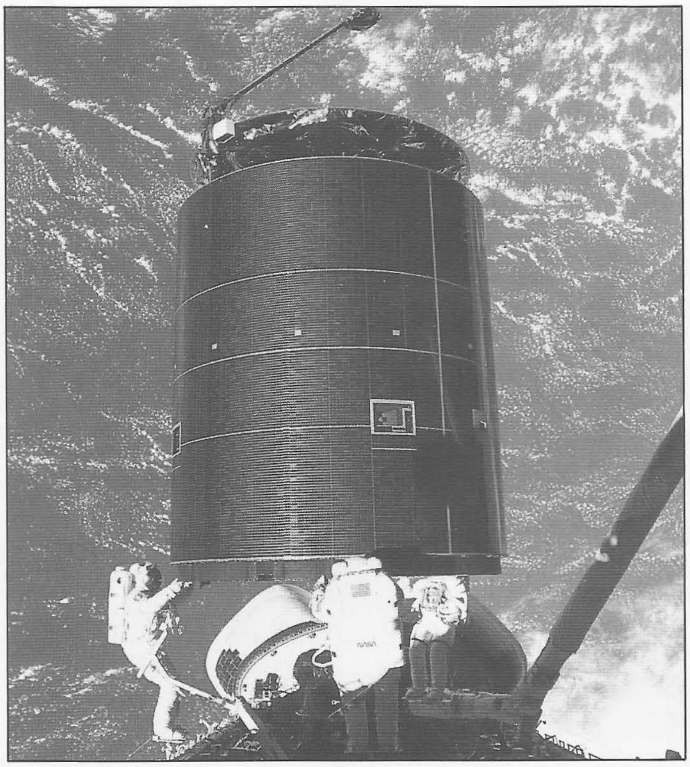
This Saturn V flight was man's first journey around the Moon and forerunner of the Apollo lunar-landing flights. The three-man crew (Borman, Lovell and Anders) set course for the Moon, passed behind it and transferred to a lunar orbit, circling the Moon ten times in 20 hours. Their many still photographs and much cine film helped to decide on landing sites for later missions. The final TV transmission took place while 97,000 miles from Earth. *22 mins*

Apollo 9: Three to Make Ready

Building on the successful flight of Apollo 8, a lunar module was tested in space, as was the life support system of the space suit. Two of the three-man crew (McDivitt, Scott and Schweickart), transferred to the Lunar Module, moved 100 miles away from the Command Module and then returned to rendezvous with it. The two men then transferred back to the Command Module and the Lunar Module was jettisoned. *17 mins*

Apollo 10: To Sort out the Unknowns

Lift-off to a trans-lunar orbit by Stafford, Young and Cernon, with views of Earth and system checks *en route*. There was loss of communications signal while passing behind the Moon as the craft transferred to lunar orbit. Signal acquisition returned when the spacecraft reappeared, with TV pictures showing the Lunar Excursion Module (LEM) undocked from the Command Module and descending to within 50,000 feet of the lunar surface. Direct communications between Control and LEM failed so access was made *via* the CM. LEM subsequently rendezvoused with the CM, the crew transferred again and LEM was jettisoned. *26 mins*



STS-49 Mission Highlights

The details of this flight by the Shuttle Endeavour, 7-16 May, 1992, are well covered, e.g. the preliminaries of suiting-up, the White Room, entry to orbiter, removal of gantry, count-down, engines start, lift-off, and detailed operations during the flight. A principal aim was to retrieve the Intelsat VI satellite which had previously failed to reach synchronous orbit. Though more difficult than expected, it was achieved and sent on its way. A second aim was to practice basic space station assembly work by Extra-Vehicular Activity (EVA). This was also very successful. The video concludes with an interesting press interview with the crew. *1hr50 mins*

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Spaceflight

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Front Cover: Lunar Outpost: Establishment of a permanently inhabited lunar outpost is a crucial step toward expanding human presence into the solar system. The outpost could expand into a network of lunar bases and ultimately a lunar settlement. *NASA*

Lunar Development, Past and

Towards an International Lunar

The Space Shuttle was flying, the Soviets were the leading nation in manned space flight and the general public in the US posed the question "Where do we go from here?"

Thus in April 1985, the President, mandated by the US Congress, appointed a "National Commission on Space" of 15 members with Thomas Paine a former Administrator of NASA as chairman. It was charged "to formulate a bold agenda to carry America's civilian space enterprise into the 21st century".

National Commission on Space

During the deliberations of the Commission the US experienced the loss of seven astronauts in the tragic accident of the Challenger spacecraft in January 1986 leading to a lengthy interruption of the US manned space flight programme. This did not deter the Commission and their report [1] was published in May 1986. It contained the recommendation "return to the Moon, not only for brief expeditions, but for longer, systematic explorations; eventually we should come to stay" among other recommendations.

The proposed schedule envisioned robotic lunar return by the year 2000, a human outpost by about 2005, a pilot propellant plant by 2007, large scale propellant production by about 2012 and the start of lunar manufacturing by about 2017! It was also realised at that time that these goals could not be accomplished without a heavy lift launch vehicle which had to be developed on a priority basis.

The Sally Ride Report

As reaction to this report developed outside of NASA, the Administrator appointed a task force headed by Sally K. Ride to come up with an outlook of the future space programme on the basis of the recommendations of the National Commission on Space. This NASA report entitled "Leadership and America's Future in Space" [2] was published in August 1987. One of the four initiatives proposed concerned lunar development, calling for an "outpost on the Moon: a program that would build on and extend the legacy of the Apollo Program, returning Americans to the Moon to continue exploration, to establish a permanent scientific outpost, and to begin prospecting the Moon's resources". Its development phases were seen as follows:

Phase I:	Search for a site (1990s)
Phase II:	Return to the Moon (2000-2005)
Phase III:	At home on the Moon (2005-2010)

It was suggested that, by the year 2010, up to 30 people would be productively living and working on the lunar surface for months at a time.

This task force also came to the conclusion that such a programme would "require a heavy lift launch vehicle and a healthy Space Shuttle fleet". It was NASA policy at that time to use the space station Freedom as a transportation node in this context.

NASA Shows Interest

NASA appointed an Assistant Administrator for Exploration, John Aron, who published his first annual report in November 1988 entitled "Beyond Earth's Boundaries" [3], which stressed the Lunar Observatory and the Lunar Outpost as case studies, promoting a return to the Moon by 2005. One of the key recommendations was a heavy-lift transportation system targeted for operational readiness by the turn of the century. One year later a special report "Lunar Outpost" [4] by the Advanced Program Office of the Johnson Space Center at Houston detailed the planning activities leading to a return to the Moon. A report presented engineering details on how to get there, what facilities to build and a preliminary programme of research on the Moon.

Space Exploration Initiative

These activities and documents prompted the US President, George Bush, to announce a "Space Exploration Initiative (SEI)" in July 1989, on the occasion of the 20th anniversary of the first landing of humans on the Moon. He challenged America to "go back to the Moon, back to the future, and this time, back to stay... And a journey into tomorrow...a manned mission to Mars". The Vice-President J.D. Quayle, as Chairman of the National Space Council, appointed a Synthesis Group to develop a blueprint for SEI. This group, with Thomas P. Stafford as Chairman, started its "outreach program" in December 1989 to solicit innovative ideas on how a future space programme should be constructed. The group was deliberately not established as a part of NASA. The RAND corporation was charged with the task of collecting the ideas and proposals instead and doing most of the evaluation. The membership of the American Institute of Aeronautics and Astronautics was also invited to make proposals. A total of 1697 submissions had to be screened; 215 were selected for a detailed analysis and presented to the Synthesis Group for further considerations [5].

Lunar Development Subcommittee of the IAA

While this activity was going on in the US, the Lunar Development Subcommittee of the IAA (International Academy of Astronautics) completed its report, which was approved during the 40th IAF Congress at Dresden, Germany in October 1990 and published a few months later as the first cosmic study of the Academy [6].This position paper concluded that the initial investment would be of the order of about $100 billion to be spent over a period of 15 years. Operational costs are near to $5 billion a year for a medium-sized lunar base. Transportation system cost would be near $1.3 billion per man year in the first year coming down to about $20 million in the 30th operational year.

The report presented a phased time schedule which envisions the activation of some formal international organisation (called the 'Lunar Development Agency') by about 1997. The first phase would have the goal of establishing a manned lunar orbiting station by 2004. The second phase would see the establishment of a lunar research laboratory no later than 2010, requiring the arrival of the first construction crew in the 2005/07 time period. To set up a major production facility on the Moon in the years 2011 to 2025 would be the goal of the third lunar development phase. An ambitious fourth phase could be a lunar settlement with a high degree of self-sufficiency by the end of the 21st century. A total of 1500 copies of this special report of the Academy were distributed to its members and government officials for further consideration.

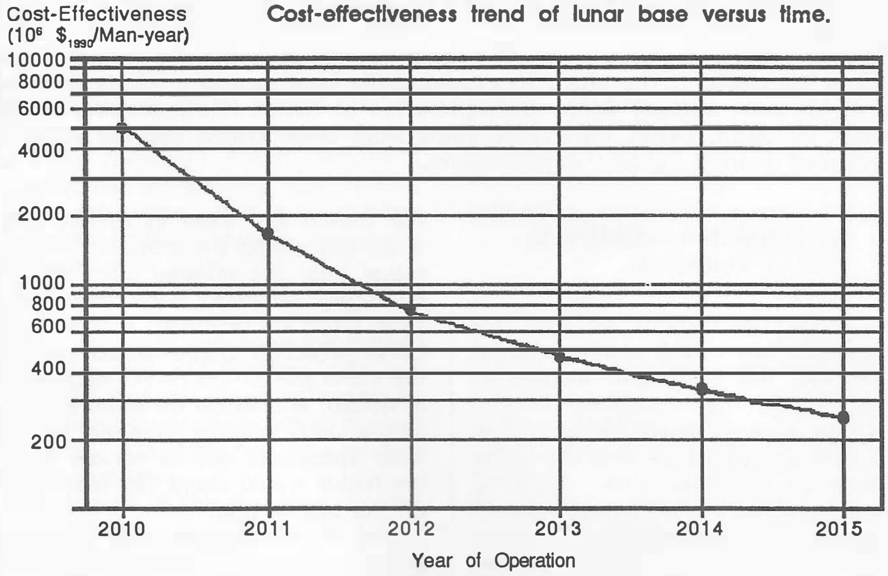
The Synthesis Group Issues Report

By May 1991 the Synthesis Group completed its survey and published its final report entitled "America at the Threshold" [5]. This contained 10 recommendations on how to continue the Space Exploration Initiative (SEI). The scenario envisioned the first piloted mission to the Moon in 2004, then gradually increasing facilities and capabilities and building up an outpost with a permanent crew of 18 by about 2007/08. Other mission models in connection with manned Mars flights were discussed. It was recognised by this time that lunar transportation will be the determining factor on the how and

Future (Part 2) Base

BY HEINZ-HERMANN KOELLE
Professor Emeritus, Technical University of Berlin

Cost-effectiveness trend of lunar base versus time.



when of a lunar base. Consequently it was recommended that the heavy lift launch requirement for the SEI was a minimum of 150 metric tons per flight with designed growth to 250 metric tons. Using the F-1 engine of the Saturn V vehicle was recommended for the first stage coupled with liquid oxygen/hydrogen engines in the upper stages and a target date of 1998!

Reduced Funding

When this report came out, the world had substantially changed. The unification of Germany in 1989 had changed the political landscape in Europe. Soon after that the Soviet Empire dissolved and the USSR space programme was severely disrupted. Funding had been greatly reduced, the ESA countries no longer being in a position to support the 1987 notion of an autonomous European manned space capability, even less the idea of a European space station. These plans were dropped in 1992 with recognition that the time for more international cooperation had come.

The change in the global environment was also felt in the US. The rapid rise of the national debt, the change in the national mood, the decreasing need for competition with the socialist countries and other needs changed national priorities. Congress was no longer so enthusiastic about space and it was unwilling to fund the SEI proposed by President Bush. The new National Launch System (NLS) received little funding and was cancelled in 1992 as it would not be big enough to support the lunar base and manned Mars missions and, in its smaller versions, it only duplicated what existed.

Thus, in October 1992, at the opening of the "World Space Congress" (which incorporated the 43rd IAF Congress) the 3000 participants could not expect early realisation of their dreams. Although more than 100 papers dealt with the issues and problems of lunar development, there was no realistic plan on how lunar development was to be achieved. It became clear that duplication of effort was out and that international cooperation was in. Even most of the participants from the US were willing to admit that the lunar base and a manned Mars expedition would probably not become a national programme under prevailing conditions.

As an International Enterprise

The IAA held firmly to the idea of an international lunar base and reinstituted its Subcommittee on Lunar Development. The report on this subject, given to the plenum of the Academy indicated extensive related activities in this area during 1991 and 1992.

Activities throughout the world indicated increasing interest in lunar exploration, such as a broad study by the European Space Agency reviewing the scientific potential [7], the critical analysis by the Office of Technology Assessment [8], a Japanese spaceprobe flying around the Moon [9], other Japanese studies [10,11,12], new work on lunar precursors [13] and detailed studies on the cost of a lunar base project [14]. The results of these latest cost estimates and projections up to the year 2015 are summarised by the diagram which gives a good overview of the funds required in $\$_{1990}$ per man-year.

Even if the prospects do not look bright for an early return to the Moon, there is encouragement to continue work. It is obvious that the lunar base project is not around the corner and also that, without US leadership, there will be no lunar base for a long time to come. The US Congress must be convinced first to get this project going and this will not happen unless other countries show interest in participating in this international enterprise.

There is not room enough to mention all relevant events and renowned contributions towards the goal of lunar exploration and the recent activities intended to lead towards a future international lunar base.

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(Part 1 of this article appeared in the February 1993 issue of **Spaceflight.***)*

First Lunar

A Special Report on NASA's

Despite a lack of funds, NASA continues a low level effort to lay the groundwork for a return to the Moon and human missions to Mars. A major milestone in this ongoing process came last autumn with the release of plans for what NASA is calling the First Lunar Outpost (FLO).

The FLO study team set out to demonstrate from preceding work [1] how a series of ambitious human lunar missions could be underway before the end of the century. The study represented the best part of a year's work by small teams of engineers based primarily at the now defunct Office of Exploration at NASA Headquarters, Washington and at NASA's Johnson Space Center, Houston, Texas. Input also came from other NASA centres such as the Marshall Space Flight Center which studied launch vehicle requirements.

BY DARREN L. BURNHAM
Oxford, UK

A Foot-Hold on the Moon

The objective of FLO would be to establish an initial foot-hold on the Moon via a modest crew-tended outpost, with teams of four astronauts staying at the facility for up to 6 weeks at a time.

The first piloted mission would be preceded by the deployment of a space station sized habitation module on the lunar surface which would be furnished with enough supplies to support the first crewed mission. The habitat would be designed to eliminate the need for any construction on the Moon, and would be fully integrated prior to launch. The philosophy used in the design of the habitat would be that of a spartan "lunar campsite", and many of the features which might be desirable for longer duration missions would be omitted from the initial design.

Shortly after landing the habitation module would automatically unfurl its solar arrays and radiators, while Ground Control would run a series of checks to confirm its habitability. Only after this had been done would the go-ahead be given for the launch of the first crew. The astronauts would land their spacecraft within walking distance of the habitat. They would then begin the process of powering down the return module, unloading the roving vehicle and transferring over to the habitation module which would serve as their base for the remainder of the mission.

For the FLO programme, the entire return spacecraft would descend to the lunar surface with the full crew of four. This is in contrast to the lunar orbit rendezvous mode used during the Apollo programme, in which a small Lunar Module carried two astronauts to the surface while a third astronaut remained in lunar orbit aboard the Command Module. With the Apollo method, engineers avoided the problem of developing extremely large launch vehicles (as required for FLO's direct mission mode). The Apollo system was rather inflexible, but given that surface stays by the Lunar Module were relatively short, the method was perfectly acceptable in the circumstances. For each of the Apollo missions, landings were made close to the equatorial regions so that the Lunar Module could easily rendezvous with the Command Module in lunar orbit.

These problems would be avoided in the FLO scenario by taking the entire spacecraft to the lunar surface. Should problems arise, the astronauts could make a quick getaway at any time, without having to wait for an opportunity to rendezvous with an orbiting spacecraft. This in turn would give the FLO lunar lander the capability to reach any part of the lunar surface.

Launch Vehicles

The penalty for adopting the direct mission mode would come with the size of the launch vehicle required to undertake the mission. For FLO, the size of the payload that needs to be placed on the lunar surface is approximately 30 tonnes, which equates to a requirement for approximately 220-230 tonnes to be delivered to LEO. This is over 1½ times greater than the payload requirements for the Apollo missions, in which approximately 130 tonnes were delivered to LEO, and 7½ tonnes to the lunar surface.

Two possible launch vehicles have been studied to meet the needs of the FLO mission. One is based on the Saturn V launch vehicle which propelled Apollo to the Moon, the other is a derivative of the now cancelled National Launch System (NLS) which NASA and the Department of Defense had been hoping to develop for use in the late 1990s. A third candidate also exists in the form of an uprated version of Russia's Energiya launch vehicle.

In the case of the Saturn V derived vehicle, the extra take-off thrust would be achieved by uprating the kerosene/liquid oxygen F-1 first stage engines (dubbed F-1A) to develop 8,000 kN of thrust. The S-1C core stage with five F-1As would be supplemented by the addition of two strap on boosters each powered by two F-1As. With a total of nine F-1A engines firing at the time of launch, the total take-off thrust of the vehicle would be a colossal 72,000 kN. The second stage would be based on the Saturn S-II used in Apollo, however, this would be provided with six rather than five uprated J-2S oxygen/hydrogen engines, each developing over 1,180 kN of thrust. A new Trans Lunar Injection Stage would perform the same job as the S-IVB stage used in Apollo, and would be powered by a single J-2S engine. Capped by the lunar spacecraft and its escape tower, the rocket would stand 125 metres tall on the launch pad.

The F-1A engine also features prominently in the second option, a two-stage vehicle based on the NLS. The core stage would comprise of four liquid oxygen/hydrogen STMEs (Space Transportation Main Engines) each developing 2,450 kN of thrust. Additional thrust would be provided by four strap-on boosters each with two F-1As, giving the combination a total take-off thrust of 74,000 kN [2]. The Trans Lunar Stage would be powered by a single STME. Fully assembled, the vehicle would stand 107 m tall.

The Lunar Spacecraft

The return capsule would house the crew during the flight to and from the Moon. It would be similar to the Apollo Command Module, although slightly larger to make room for the extra crew member. The return capsule would bypass the Space Station Freedom, and just like Apollo, would make a direct reentry into the Earth's atmosphere. However, the homecoming would be made on the "brown" rather than the "blue" part of the Earth's surface. To facilitate a soft-touchdown on dry land, a retrorocket system would be used to augment the main parachutes.

The desire to avoid ruinous costs pervaded at all levels of the study, and engineers strove to achieve the widest range of applications possible with the minimum initial outlay of hardware. An example of this would be the use of identical lunar landing stages for both the habitat module and the crew return vehicle. Weighing 60 tonnes, the four-legged lander would be propelled by four modified RL-10 liquid hydrogen/oxygen engines, adjusted for 4:1 throttling.

The return stage would most likely use storable hypergolic propellants so that a return to Earth could be set in

Outpost
Latest Plans for the Moon

motion quickly in an emergency. Unlike Apollo where the astronauts were reliant upon a single engine for the ascent from the Moon, three engines would propel the FLO return stage.

Lunar Science

Scientific activities undertaken by the crew while on the surface would be broadly similar to those conducted during Apollo, although a more concerted effort would be made to harness the Moon's potential as a stable platform for high quality astronomical observations.

Paired off into two teams, each astronaut could face the prospect of making as many as three, eight-hour EVAs during each week spent on the lunar surface. During these EVAs the astronauts would make use of an unpressurised rover with a range of about 25 km. The rover would be a larger version of the Apollo Lunar Roving Vehicle (LRV), so that it could be used to transport all four crew members, or a variety of heavy payloads. Unlike the Apollo LRV, it would also be possible to operate the FLO rover under remote control from Earth. With this facility, it could be used for longer traverses (about 200 km) while no crew is present at the outpost.

EVA activities would include the deployment of a package of experiments including geophysical monitoring stations and research telescopes, and extensive geological and geophysical investigations to fully characterise the terrain around the habitat. While on the surface the crew would also conduct initial experiments to demonstrate processes for the utilisation of lunar resources.

While crew members are ensconced in the habitat, a series of life science studies would investigate the effects of the lunar environment on human physiology. The astronauts would also prepare the collected rock and soil samples for return to Earth. In all, a combined total of 200 kg of lunar rock and biological samples should be returned to Earth at the end of the mission.

After a stay of two lunar days and one complete lunar night the crew would deactivate the habitat and transfer back over to the return vehicle to begin the journey back home.

Return Visits Planned

Further missions to the habitat would follow at roughly six-monthly intervals, with each subsequent crew bringing their own consumables with them. Surface experiments would progressively become more sophisticated - such as the deployment of a radio telescope antenna - while geological traverses would build upon the findings of earlier crews.

After the completion of several missions of this type, a variety of options would be available for the future in line with the "waypoint" strategy espoused by the Synthesis Group. The least expensive of these would be to maintain the outpost near its initial capabilities. Conceivably, additional equipment could be added to the habitat to make conditions more comfortable for the astronauts, thus enabling a modest increase in mission duration (60-90 days). Alternatively, a second habitat could be launched to a new site, allowing local science activities to be repeated at a different location. The most far reaching proposal would result in the use of the initial outpost as a "construction shack" for the establishment of a more permanent presence by a larger crew. An early base of this type could also be used to support preparations for the first human missions to Mars which NASA views as a logical outgrowth from FLO.

In almost every conceivable respect FLO would provide a significantly enhanced capability for the exploration of the Moon, across a broader range of disciplines than were tackled in the Apollo programme. Statistics can be misleading, but the 180 crew-days on the lunar surface which could be amassed during each FLO sortie would dwarf the 25 crew-days accumulated during the six Apollo landings. A comparison of EVA time is no less impressive, as each FLO mission could clock-up a three to four fold increase over the 162 crew-hours achieved in the Apollo programme.

Whereas each Apollo mission was quite literally a race against the clock, the FLO astronauts would face a much less constrained timetable. Besides nurturing a more systematic approach to geological investigations, the extra time would also give the crew the chance to capitalise upon serendipitous discoveries. Should the FLO astronauts stumble upon the discovery of something akin to Apollo 15s "Genesis" rock, or Apollo 17s "orange soil", the chance of making a return visit would always remain. However, with the finite amount of time available to them, the Apollo astronauts were always fighting a losing battle, and had no other choice but to press on to the next site.

Each flight to the Moon requires a single launch. *NASA*

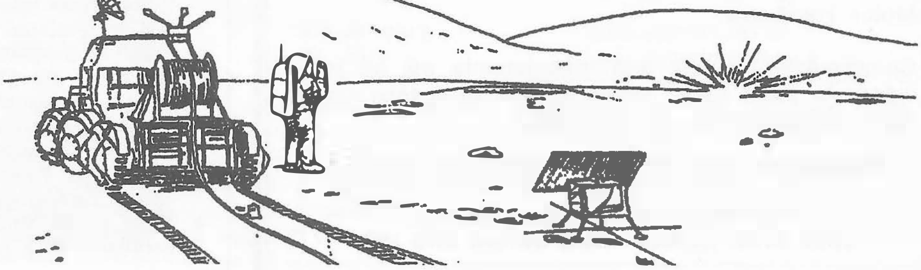
Another area in which FLO could be expected to contribute many ground breaking discoveries would be in the field of astronomy. Astronomers have long recognised the benefits of placing arrays of telescopes on the Moon, but this is one aspect of lunar science which the Apollo programme, with its much narrower parameters, barely scratched the surface of.

Besides learning about the Moon and our place in the universe, mankind should also discover much about itself, for FLO could provide the human race with its first opportunity to learn how to live on another planetary body over an extended period of time. In this way it might be possible to better assess many of the imponderables which stand in the way of sending crews on the long haul to Mars.

A Road to Nowhere?

Impressive as these plans undoubtedly are on paper, not everybody is convinced that FLO represents the right way to proceed. The overriding fear is that in pinning its hopes on Apollo type, one-shot technology, NASA would run the risk of creating for itself yet more hardware which it could

Science and surface exploration activities are included in the programme. *NASA*



not possibly afford to use on a long-term basis. FLO's detractors also point out that the use of the "Outpost" title may paint a slightly misleading picture, for it can be taken to imply a sustained long-term commitment to lunar exploration. However, critics have argued that what NASA is in fact proposing is little more than an elaborate multiple expedition to the Moon, which is hauntingly familiar of various Apollo extension programmes proposed in the 1960s.

Even the most fervent advocates of lunar exploration caution that in trying to sell FLO simply on the basis of the numerous gains that the programme could contribute to science, NASA may be approaching the problem from the wrong direction. Do the job properly in the first place - that is to say, set out with the intent of developing a permanently crewed lunar base - and the science will take care of itself once the appropriate Infrastructure elements are in place, along with many other barely Imagined possibilities. Having waited this long for a return to the Moon, there is good reason to ask why now rush into things with a programme which arguably bears the hallmark of being little more than a bigger brother of Apollo?

NASA officials are at pains to play down such criticisms. The fact that some of the engineering solutions adopted for FLO bear a strong resemblance to Apollo should come as no great surprise, for the laws of nature which now govern flights to and from the Moon are the same laws which applied to Apollo in the 1960s. It is also claimed that far from diverting attention away from the development of a permanently crewed lunar outpost, FLO represents an appropriate first step toward this goal, for it would both provide an early payback on investment, and the nucleus from which such a settlemnt could later emerge.

Money for Nothing

While the FLO study is one of the most detailed assessments of human lunar missions that the space agency has prepared since the end of the Apollo programme, NASA stops far short of calling the nascent study a definitive baseline mission. The space agency has been unable to define the cost of the programme, since so many engineering Issues have not been examined in close detail. The only guide to likely costs has come from Michael Griffin, the former Associate Administrator for Exploration, who reportedly said that NASA would find it difficult to mount a meaningful lunar programme costing less than several billion dollars per year [3].

It is perhaps just as well that the likely cost of the FLO programme remains a matter for speculation, for money has always been the achilles heel of NASA's Space Exploration Initiative (SEI). With the federal budget deficit currently standing at over $300 billion, few in Washington have been willing to stand up and voice support for the notion of human missions to the Moon and Mars. The most recent sign of opposition to the SEI came with the rejection of NASA's plans to Initiate development of a series of robotic lunar precursors which would help pave the way for later human missions. The agency had requested $32 million to make a start on this programme in FY-93, of which $29 million was to have been set aside for the precursor missions. Yet, although the precursors offer a potentially winning combination of high quality science at a reasonable cost, Congress turned down this request with relatively little argument [4].

There is little evidence to suggest that the SEI has many friends within the general public either. For example, the findings of a recent opinion poll suggest that as many as two-thirds of American taxpayers believe that NASA's annual budget - for what is after all a rather modest agenda comprising of six to eight Shuttle launches per year, development of the Space Station Freedom, and a broad range of scientific activities - is somewhere in the region of $200 to 300 billion. Yet in recent times, NASA's annual budgets have typically been in the region of a much more modest $12 to 15 billion. Given that human missions to the Moon and Mars are commonly perceived as something which are infinitely more expensive than NASA's current activities, it is apparent that the agency is going to have its work cut out if it is to convince the public at large that it can afford these type of ventures in such fiscally austere times as these.

There is widespread agreement that the SEI (which is in any case a left-over from the administration of former President George Bush) has been overtaken by events, leaving the results of the FLO study to be largely a matter of academic interest. In what is seen In some quarters as a long overdue step to cut NASA's losses on the SEI, Chief Administrator Daniel Goldin announced March 25th that he was closing down the Office of Exploration and transferring its functions to the Office of Space Science, headed by Dr Wesley Huntress. Michael Griffin, who moved to NASA in 1991 to take charge of the exploration programme now becomes the agency's Chief Engineer.

As NASA grapples with the task of redesigning the Freedom Space Station as mandated by President Bill Clinton, the emphasis of what remains of the Moon-Mars effort will now focus almost exclusively on more immediate robotic precursor missions. FLO meanwhile - and a long awaited Mars mission study which was due to have been released later this year - seem destined to remain on the back burner for some considerable time to come.

Notes and References

1. Report of the Synthesis Group on America's Space Exploration Initiative, "America at the Threshold", US Government Printing Office, Washington, May 1991. (See also the accompanying article by Professor Heinz-Hermann Koelle for more background).
2. Historical Note: both the Saturn V and NLS derived vehicles are larger than the 53,000 kN Nova, the largest variant of the Saturn family of boosters which NASA studied in the early 1960s as a possible launch vehicle for Apollo. In comparison, the original Saturn V developed a "mere" 33,400 kN at take-off.
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BIS Visit

Royal Ordnance
Rocket Motors Division
Westcott

1933
1993

The Society is pleased to announce that, as part of its 60th Anniversary Celebrations, a visit for Society Members will be made to Royal Ordnance Rocket Motors Division, Westcott, formerly the Rocket Propulsion Establishment on 14 July 1993.

The agenda for the day will include three briefings:

- *Background and History*
- *Site Operations*
- *Current Products and Markets*

Solid and Liquid Propellant Motor Firing Sites will be toured along with a visit to the Exhibition of Rocket Motor Hardware.

Complimentary Lunch and refreshments will be provided. As there are a limited number of spaces available pre-registration Is necessary.

Registration forms and location maps are available from:
The British Interplanetary Society
27/29 South Lambeth Road, London SW8 1SZ

NASA Plans New Solar System Missions

'A Bold New Way of Doing Business at NASA', Claims Dan Goldin

NASA has announced the selection of 11 new science mission concepts for further study during this fiscal year. They were selected from 73 concepts discussed at the Discovery Mission Workshop held in November 1992. Discovery missions are designed to proceed from development to flight in less than 3 years, combining well-defined objectives, proven instruments and flight systems with costs limited to no more than $150 million and acceptance of a greater level of risk.

The 11 new mission concepts follow the first two Discovery missions which were selected last year for Phase A studies. These are the Mars Environmental Survey (MESUR) Pathfinder, planned for launch in 1996, and the Near Earth Asteroid Rendezvous (NEAR), planned for a 1998 launch.

Phase A studies of the MESUR Pathfinder mission were awarded to NASA's Jet Propulsion Laboratory, Pasadena, California (JPL). The Applied Physics Laboratory of Johns Hopkins University, Baltimore, Md (APL), was awarded Phase A studies of the NEAR mission.

MESUR Pathfinder is a technical demonstration and validation flight for the MESUR programme, scheduled to begin in 1999. The MESUR programme calls for building a network of about 16 small automated surface stations widely scattered around Mars to study the planet's internal structure, meteorology and local surface properties.

NEAR would spend up to a year station-keeping with a near-Earth asteroid and would probably carry only three instruments to assess the asteroid's mass, size, density and spin rate, map its surface topography and composition, determine its internal properties and study its interaction with the interplanetary environment.

The 11 new mission concepts are:

1. *Mercury Polar Flyby:* to study the polar caps and complete the photographic reconnaissance of the planet. Principal Investigator: Paul D. Spudis, Lunar and Planetary Institute, Houston.
2. *Hermes Global Orbiter to Mercury:* to remote sense the planet's surface, atmosphere and magnetosphere. Principal Investigator: Robert Nelson, JPL, Pasadena, California.
3. *Venus Multiprobe Mission:* to place 14 small entry probes over one hemisphere of Venus to measure winds, temperature and pressure. Principal Investigator: Richard Goody, Harvard University, Cambridge, Massachussetts.
4. *Venus Composition Probe:* to enter Venus' atmosphere in daylight to measure atmospheric structure and composition on a parachute descent. Principal Investigator: Larry W. Esposito, University of Colorado, Boulder.
5. *Cometary Coma Chemical Composition:* to rendezvous with a cometary nucleus at or near perihelion and conduct 100 days of scientific operations. Principal Investigator: Glenn C. Carle, NASA Ames Research Center, Mountain View, California.
6. *Mars Upper Atmosphere Dynamics, Energetics and Evolution Mission:* to study Mars' upper atmosphere and ionosphere. Principal Investigator: Timothy Killeen, University of Michigan, Ann Arbor.
7. *Comet Nucleus Tour:* to study three comets during a 5-year mission, focusing on structure and composition of the nucleus. Principal Investigator: Joseph Veverka, Cornell University, Ithica, New York.
8. *Small Missions to Asteroids and Comets:* to launch four separate spacecraft to study distinctly different types of comets and asteroids. Principal Investigator: Michael Belton, National Optical Astronomy Observatories, Tuscon, Arizona.
9. *Near Earth Asteroid Returned Sample:* to acquire samples from six sites on a near-Earth asteroid and return them to Earth for study. Principal Investigator: Eugene Shoemaker, US Geological Survey, Flagstaff, Arizona.
10. *Earth Orbital Ultraviolet Jovian Observer:* to study the Jovian system from Earth orbit with a spectroscopic imaging telescope. Principal Investigator: Paul Feldman, Johns Hopkins University, Baltimore.
11. *Solar Wind Sample Return Mission:* to collect and return solar wind material to Earth for analysis. Principal Investigator: Don Burnett, California Institute of Technology, Pasadena.

A formal competition to make final selections of the missions to be conducted will be announced possibly in 1994. The Discovery Program is managed by the Solar System Exploration Division of the Office of Space Science and Applications, NASA Headquarters, Washington, DC.

BIS Joint Event . . . Enrol Now !!

As a sequel to the TV programme 'Mars Alive' the Society and Birkbeck College, University of London, Centre for Extra-Mural studies (CEMS) announce a Two Day Weekend School organised by Dr R.L.S. Taylor and members of the CEMS Astronomy team.

Bringing Worlds to Life

to be held at

The Centre for Extra-Mural Studies, 26 Russell Square, London WC1B 5DQ
Saturday and Sunday, 15 and 16 May 1993
(To Mark the Occasion of the Diamond Jubilee of the Society)

Programme and Speakers (provisional)

Day 1 *Chaired by L.J. Carter, BIS*

1. The Human Impact of the Earth's Environment: Prof A. Goudie, University of Oxford.
2. Terrestrial Trends of Human Induced Changes in the Earth's Biospheric Environment: Prof I.G. Simmons, University of Durham.
3. The Nature and Resources of the Surface of Mars: Dr P. Catermole, University of Sheffield.
4. Beyond the 'Horizon' of 'Mars Alive' - The International Research into Terraforming and Planetary Environmental Engineering: P. Ceresole, BBC Horizon Science Producer.
5. Planetary Science Bases - Steps Towards Colonization: Dr R. Parkinson, BAe.

Day 2 *Morning and Afternoon*

1. Terraforming Mars - The Warming - Biogeological Scenario. Video Taped Lecture Specially prepared for the Weekend School: Dr C. McKay, Ames Laboratory, NASA.
2. Methods of Inducing Planetary Change - Two Great Projects Mars & Venus: M. Fogg, Probability Research Group.
3. The Mars Atmosphere Problem - The Worldhouse Solution and Its Wider Applications: Dr R. Taylor, Birkbeck College, U.o.L.
4. Custom Built Planets - Move Over Slartybartfast!: P. Birch, BIS.
5. Summing Up the Present and Looking at Future Trends.

Terraforming

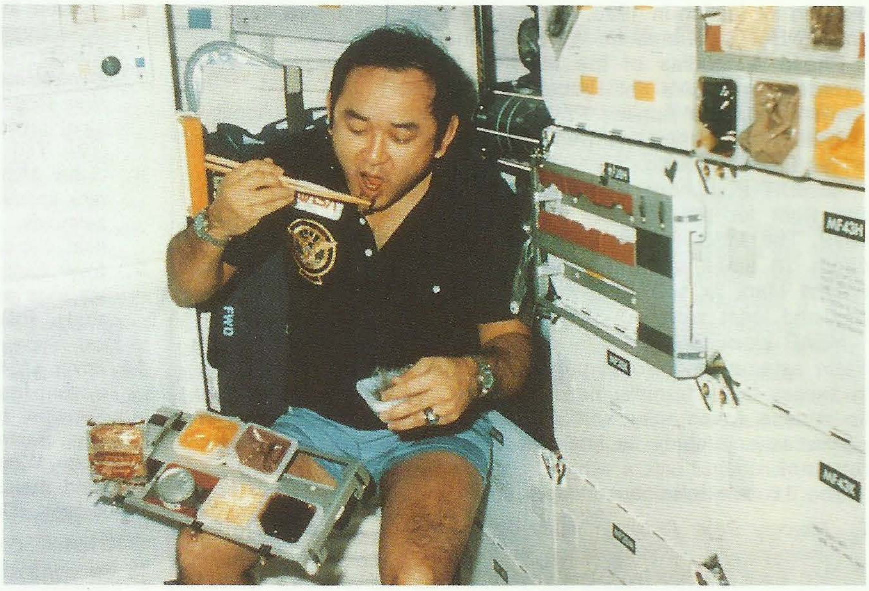
The New Science of Planetary Environmental Engineering

The idea that other planets might be made habitable for humans and other forms of terrestrial life became a subject of serious scientific speculation and study more than 25 years ago. The word 'terraforming' describes this process of planetary transformation to one that is Earth-like in all important respects. Ideally a completely terraformed planet will possess a stable self-regulating ecosphere in which the prevailing conditions fall within the range of human physiological tolerance.

The study of how planetary environments can be re-engineered and changed and maintained as suitable for life - the study of terraforming - is something that is as important for the long term preservation of life on Earth as it is for the establishment of permanent human settlements away from our home planet.

Registration details, attendance fees etc are available from:
Ms. Leslie Hannigan, Astronomy Desk, Centre for Extra-Mural Studies, 26 Russell Square, London WC1B 5DQ; Tel: 071-631 6627. As Accommodation is Limited, Early Registration for this Exciting and Popular Study School is Strongly Advised.

A previouly unpublished photograph of the crew of STS-51J during the second military shuttle mission in October 1985. Clockwise, from left - Karol Bobko, David Hilmers, Ronald Grabe, Robert Stewart and William Pailes (USAF). *NASA*



The first photograph to be released from a military shuttle flight was this in-flight portrait of Challenger astronaut Ellison Onizuka. *NASA*

Tom Henricks, pilot of the second unclassified military shuttle flight (STS-44), peers into the Visual Function Tester apparatus during a space vision test. *NASA*

Beginning with STS-27 a small selection of photographs was released after each military flight. In this photograph astronaut Guy S. Gardner, STS-27 pilot, is surrounded by cameras on the flight deck of the Earth-orbiting Atlantis. *NASA*

'Secret' Shuttle Payloads Revealed

Prior to the 15th flight of the Space Shuttle in January 1985, each American manned space mission had been conducted with full and open disclosure to the public. When the orbiter Discovery lifted off from Kennedy Space Center carrying a secret military payload on 24 January 1985, the most newsworthy aspect of flight 51-C was not the unseasonably cold weather or the military cargo, but the total lack of information available about even the most insignificant detail of the flight.

BY JOEL W. POWELL
Space Information Canada

All relevant information about flight 51-C was classified secret including the scheduled launch time and window, the mission duration and the secondary experiments, payload and vehicle weights. Such details had always been provided by NASA in the past. Even the routine NASA engineering and medical tests conducted on every shuttle flight (the so-called DTO's and DSO's) were concealed behind a veil of secrecy and the traditional post-flight release of mission photography was withheld from the public for the first time. The only concession to openness by the Department of Defense (DOD) was a reluctant admission that the Inertial Upper Stage (IUS) was being carried on the flight for the first time since the near disastrous TDRS satellite deployment in April 1983.

Despite the information embargo, the *Washington Post* newspaper caused a sensation prior to the flight when it leaked the identity of the supposedly secret electronic eavesdropping payload. Pentagon officials perceived the disclosure as a threat to national security and threatened to retaliate against the newspaper. The veiled threats failed to deter the press and speculation about the nature of the secret payloads continued until the leaks apparently dried up prior to mission STS-38, the final classified mission in November 1990.

Gary E. Payton was a member of the new category of military astronauts and the first to fly on a shuttle mission (STS-51-C). *NASA*

Military Shuttle Missions

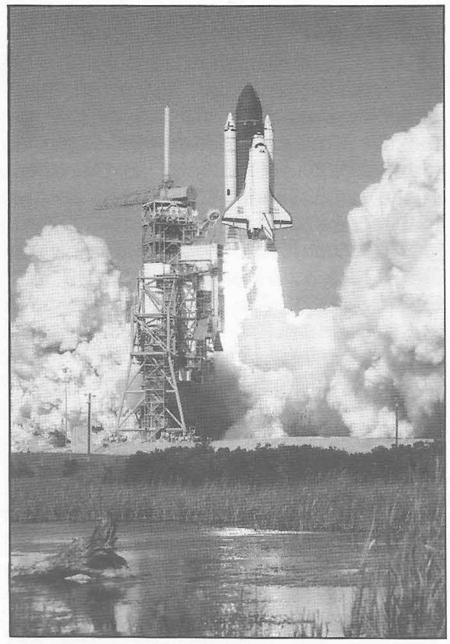
The first application of military secrecy in the shuttle programme occurred during the flight of STS-4 in June 1982. Aboard the fourth test flight of Columbia was the first Defense Department payload, a package of scientific instruments that reportedly "bumped" the originally manifested NASA payload. In a test of the security measures designed to protect future military missions, the DOD classified the payload and refused to release any photographs of the hardware or the shuttle cargo bay.

Despite security restrictions, details of the payload were quickly uncovered by the media from unclassified Congressional documents. The primary payload was identified as the Cryogenic Infrared Radiance Instrument for Shuttle (CIRRIS-1), part of payload R11 of the DOD's Space Test Program (STP) which is discussed in the section below. Ironically the same payload (with several changes) flew again nine years later on the first unclassified shuttle mission, STS-39.

Television coverage of the cargo bay during STS-4 was withheld from NASA Select, the space agency's public broadcast feed, but all air-to-ground radio traffic and in-cabin television was permitted to be released. Any hope that this form of partial classification would prevail for the operational military missions was dashed by the total information blackout imposed for mission 51-C in January 1985.

The first military shuttle flight was originally scheduled to fly in December of 1983. After the IUS stage malfunctioned during the maiden voyage of Challenger, STS-10 was cancelled along with two other military flights with IUS stages (missions 41-E and 41-H). The STS-10 crew, commanded by Apollo veteran Thomas Mattingly, was later reassigned to mission 51-C (presumably with the same IUS-boosted payload).

One of the personnel assigned to Mattingly's crew was a member of a new category of military astronauts, the Manned Spaceflight Engineers



The most newsworthy aspect of flight 51-C, launched on 24 January 1985, was the total lack of information about even the most insignificant detail of the flight. *NASA*

[1]. The Defense Department arranged that one MSE astronaut would replace a NASA Mission Specialist on each military shuttle flight - Gary Payton was the MSE assigned to 51-C, while William Pailes flew on mission 51-J. The MSE groups were forced to disband after the Challenger accident when space agency policy regarding shuttle passengers was changed. Not only were non-professional astronauts (i.e. payload specialists) excluded from shuttle crews for at least two years after the resumption of flights, but NASA also decided to assign their own astronauts exclusively to the military missions in lieu of MSE personnel.

After only seven secret shuttle missions had been flown in a five year period (compared to the 19 flights indicated for the first 101 flight opportunities in the June 1984 manifest), the Defense Department announced in 1990 that it was abandoning the Space Shuttle as a means of orbiting their so-called national security payloads. These payloads were transferred to the newly developed Titan IV expendable rockets. The high cost of maintaining security for each secret mission was cited as one of the factors in the decision. Three additional shuttle flights were booked by the military, but with the exception of the identity of the DOD-1 payload on STS-53, these missions were almost totally open.

Testing the Bounds of Secrecy

The first indication that the security restrictions were not all-inclusive came in the wake of the Challenger accident. In early 1986 the photo office at the Johnson Space Center in Houston quietly released a picture of Chai-

TABLE 1: Secondary Payloads on the Military Shuttle Flights

STS-51C *(January 24-27, 1985)*
Radiation Monitoring Equipment (RME); Cloud Logic to Optimise use of Defense Systems (CLOUDS); OCEANS (not an acronym); Storable Fluids Management Demonstration (SFMD); Aggregation of Red blood Cells (ARC - NASA sponsored); *Interim Operational Contamination Monitor (IOCM); *Orbiter Experiment Autonomous Supporting Instrumentation System (OASIS).

STS-51J *(October 3-7, 1985)*
Air Force Maui Optical Site Calibration Tests (AMOS); CLOUDS; Contrast Sensitivity Test (CST); Measurement of Atmospheric Radiance Camera - Day/Night (MARC-DN); OCEANS; RME; Biostack Middeck Experiment (BIOS - NASA sponsored); Reaction Time-Perception Analyser (RTPA); Visual Function Tester-1 (VFT-1); **Window Contamination (WINCON); *OASIS.

STS-27 *(December 2-6, 1988)*
AMOS; Auroral Photographic Experiment (APE); CLOUDS; Cosmic Ray Upset Experiment (CRUX - NASA sponsored); RME-III; Spaceborne Direct View Optical System (SPADVOS) and Battleview; Visual Function Tester-2 (VFT-2); *OASIS.

STS-28 *(August 8-13, 1989)*
AMOS; CLOUDS; CRUX; RME-III; Latitude Longitude Locator (L3); Shuttle Activation Monitor (SAM); VFT-2; M88-1; *Heavy Ion ENvironment at Low Altitudes (HIEN-LO); *IOCM; *Ascent Particle Monitor (APM).

STS-33 *(November 22-27, 1989)*
AMOS; APE-B; CLOUDS-1A; RME-III; VFT-1.

STS-36 *(February 28 - March 4, 1990)*
RME-III; VFT-1; VFT-2.

STS-38 *(November 15-20, 1990)*
AMOS; APE-B; VFT-1; SPADVOS.

** Cargo bay secondary payload ** Indicates flown as DSO*

lenger astronaut Ellison Onizuka from his only previous space flight, mission 51-C. The unexpected publication of this photograph in *National Geographic* magazine prompted the author to request additional 51-C photographs from JSC as well as the previously unpublished 51-J crew portrait that accompanies this article.

With the chance discovery of the DTO/DSO listings from STS-27 and STS-28 at JSC's History Office, the author requested further information and was referred to the Center's Freedom of Information Act representative. The FOIA office provided additional DTO/DSO lists but had to direct the author to the Air Force Systems Division in Los Angeles on the matter of the secondary payloads. The Air Force willingly supplied the record of secondary experiments (reproduced here as Table 1), but declined to release vehicle weights, launch windows or scheduled launch or landing times, citing national security reasons for their decision.

Military Secondary Payloads

The secondary payload list discloses the initial flights of several familiar experiments that later appeared on non-military shuttle flights. The first flight of AMOS, for instance, the series of ground-based observations of shuttle thruster firings and water dumps used to calibrate the Air Force Maui Optical Site (AMOS), occurred on mission 51-J in October 1985. AMOS has also been conducted on a dozen civilian missions since that time.

OASIS (see Table 1), the elaborate cargo bay contamination monitoring payload that accompanied the two TDRS/IUS combinations on both STS-26 (Return to Flight) and STS-29, actually made its orbital debut on mission 51-C, which also carried an IUS stage. OASIS flew for a second time on mission 51-J. It may be noted that the primary payloads on 51-J were recently verified in unclassified government documents as Defense Satellite Communication System (DSCS III) satcoms, vehicles B-4 and B-5. The Interim Operational Contamination Monitor (IOCM) and the Ascent Particle Monitor (APM) have flown several times since the Challenger accident, and first appeared in shuttle cargo bays on mission 51-C and STS-28, respectively.

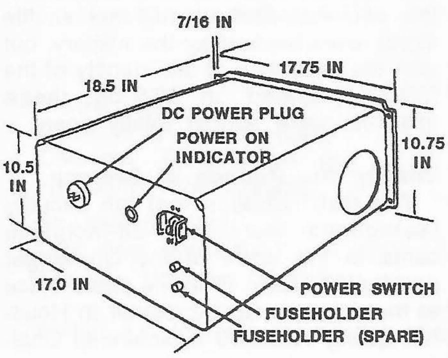
The Defense Department has demonstrated an active interest in the radiation levels aboard orbiting shuttles. Military sponsored experiments such as RME (Radiation Monitoring Equipment) and SAM (Shuttle Activation Monitor) have flown on both military and civilian flights since 1983. The DOD even co-sponsored a medical test with NASA involving a specially preserved human head embedded with radiation detectors. The so-called "Phantom Head" (DSO 469) originally flew on two military missions (STS-28 and STS-36) as well as the Hubble Space Telescope deployment mission (STS-31).

Four middeck experiments sponsored by NASA were also manifested on the military flights. After being removed from mission 51-A due to weight and centre of gravity reasons, the Aggregation of Red Cells experiment was reassigned to flight 51-C with the approval of the Defense Department. Flown on behalf of Australian medical researcher Dr Leopold Dintenfass, ARC provided data on the rate of formation and the morphology of red blood cells in microgravity. A joint DOD-NASA investigation designated the Storable Fluids Management Demonstration (SFMD) accompanied ARC on STS-51C. That same apparatus, designed to explore the dynamics of fluid transfer in space conditions, was recently flown for a second time on STS-53.

The Biostack middeck experiment (BIOS) was flown aboard mission 51-J for Dr S.L. Bonting of the University of Nijmegan in the Netherlands. The purpose of this experiment was to assess the damage to biological specimens from cosmic rays. The only NASA payload to fly on a post-Challenger DOD mission was the middeck version of the Goddard Space Flight Center's Cosmic Ray Upset Experiment (CRUX). The middeck version of CRUX flew on STS-27 and STS-28 as a follow-on to an earlier investigation flown in Getaway Special canisters to register the effects of cosmic ray impacts on computer chips.

Only one experiment on a military

The CRUX middeck experiment which was the only NASA payload to fly on a post-Challenger DOD mission.



References

1. Michael Cassutt, "The Manned Spaceflight Engineer Programme", ***Spaceflight*, 31**, January 1989, pp.26-33.
2. SAMPEX Press Kit (NASA, June 1992).
3. Joel W. Powell, Lee R. Caldwell, "Space Shuttle Almanac", Microgravity Press, Calgary, Alberta, Canada (1992).
4. Joel W. Powell, "The Space Test Program - An Update", ***JBIS***, 40, 1987 (pp.513-518).

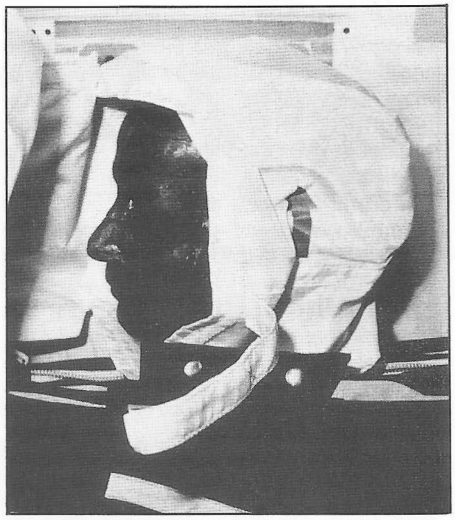
flight apparently utilised Getaway Special hardware mounted in the shuttle cargo bay. Instruments for the Heavy Ion Environment at Low Altitudes (HIEN-LO) experiment were placed in GAS cans for the STS-28 mission in August 1989. Modified versions of these instruments were later incorporated into NASA's SAMPEX (Solar Anomalous and Magnetospheric Particles Experiment) satellite that was launched from Vandenberg Air Force Base in July 1992. The two SAMPEX experiments were designated LEICA (the NASA Low Energy Ion Composition Analyser) and HILT (Heavy Ion Large Telescope), which was provided by the Max Planck Institute for Extraterrestrial Physics in Garching, Germany.

The manned space surveillance hardware operated by Army Warrant Officer Thomas Hennan during STS-44, the second unclassified shuttle mission, had been extensively evaluated during several previous secret missions. The 215 kg Spaceborne Direct View Optical System (SPADVOS, code name Terra Scout) reportedly first flew on the STS-27 mission, then again on STS-38 in November 1990. The Battleview observation system from STS-44 was also operated on STS-27. The balance of the STS-44 surveillance gear, collectively known as experiment M88-1, were first tested on STS-28. These experiments included MOSES (Maritime Observation In Space), Space Debris Belt Characterisation and the Night Mist encrypted communication system.

Being concerned with what military observers could actually see of the Earth from space, it is also logical that the Defense Department would be interested in the visual acuity of their observers. Beginning on mission 51-J a two-part experiment dubbed the Visual Function Tester (VFT) has been conducted on a number of shuttle flights. The difference between the individual hand-held VFT-1 and VFT-2 apparatus was the diversity and type of displayed symbols that were used to assess the effects of microgravity on visual performance. VFT was conducted by the Armstrong laboratory at Wright-Patterson Air Force Base in Ohio.

The Space Test Program

Most of the military middeck experiments were sponsored by the Space Test Program (STP), the tri-service body organised at the Pentagon in 1965 to oversee all Defense Department space research projects. STP serves as the liaison between the military and NASA to place relatively simple experiments aboard the shuttle in a project designated Quick Response Shuttle Payloads (QRSP). These experiments include the Auroral Photography Experiment(APE), Radiation Monitoring Equipment (RME-III), the CLOUDS and OCEANS observation investigations and the High Precision Target Experiment (HPTE), a target mirror for Earth-based laser beams carried on NASA's 51-G mission in June 1985. Larger and more elaborate middeck experiments from recent missions, such as the Battlefield Laser Acquisition Sensor Test (BLAST), the Latitude-Longitude Locator (L3) and its follow-on Hercules geographical position locator are also sponsored by STP.



The "Phantom Head" experiment in position on the shuttle's middeck. *NASA*

Shuttle Crew Announcements

STS-59

USAF Colonel Sidney M. Gutierrez will command the STS-59 Space Radar Laboratory mission aboard Atlantis. Other crew members are USAF Colonel Kevin P. Chilton as Pilot and mission specialists Jay Apt, PhD, and Michael R. "Rich" Clifford, USA Lt. Colonel. Previously announced crew members are Linda M. Godwin, PhD, named Payload Commander in August 1991 and Thomas D. Jones, PhD, named mission specialist in February 1992.

The Space Radar Laboratory, STS-59, will take radar images of the Earth's surface for Earth system sciences studies including geology, geography, hydrology, oceanography, agronomy and botany; gather data for future radar system design including the Earth Observing System, and take measurements of the global distribution of carbon dioxide in the troposphere.

STS-60

Sergei K. Krikalev has been selected as the prime mission specialist and Vladimir G. Titov as the backup mission specialist on the STS-60 mission currently scheduled for launch in November 1993.

The two cosmonauts have been undergoing mission specialist training at NASA's Johnson Space Center, Houston, since early November 1992. Charles F. Bolden, Jr. (Col. USMC) is the STS-60 Commander. The other US crewmembers are Pilot Kenneth S. Reightler, Jr. (Capt. USN), and mission specialists Franklin R. Chang-Diaz, PhD, N. Jan Davis, PhD and Ronald M. Sega, PhD.

STS-61

Astronaut Gregory J. Harbaugh is assigned as backup EVA crew member for STS-61, the Hubble Space Telescope (HST) maintenance mission.

STS-62

USAF Colonel John H. Casper will command the STS-62 mission with the second US Microgravity Payload and the second Office of Space and Terrestrial Applications payload, called OAST-2, aboard Columbia. Other crew members are USMC Major Andrew M. Allen as Pilot and mission specialists USN Commander Pierre J. Thuot, USA Lt. Colonel Charles D. "Sam" Gemar and Marsha S. Ivins.

Experiments on STS-62, a 13-day extended duration orbiter mission, include growing crystals of semiconductor materials; investigating the properties of xenon during phase transitions, investigating the fundamental behaviour of materials as they solidify into structures known as dendrites and monitoring equipment that will measure and record disturbances in the microgravity environment of the USMP carrier.

*

Mae C. Jemison, MD, who was a science mission specialist on STS-47, Spacelab-J in September 1992 and had the distinction of having been the first woman of colour in space, left NASA on March 8 to pursue interests in "teaching, mentoring, health care issues and increasing participation in science and technology of those who have traditionally been left out".

*

The ESA astronaut Dr Wubbo J. Ockels, has been appointed to the ESTEC Professorial Chair in the faculty of Aerospace Engineering at the Technical University, Delft. He flew as payload specialist on the highly successful Spacelab D-1 mission in 1985 and is presently active in preparations for European manned space flight activities. Dr Ockels sees his new duties, which will include weekly lectures and tutorials, as being a significant challenge to stimulate the coming generations of technical specialists to seek careers in the European aerospace community.

Society News

SPACE '93

Theme: Space Initiatives

A UNIQUE SOCIETY MEETING TO CELEBRATE OUR 60 YEARS DEVOTED TO ADVANCING THE CAUSE OF SPACE FLIGHT

White Rock Theatre, Hastings, E. Sussex

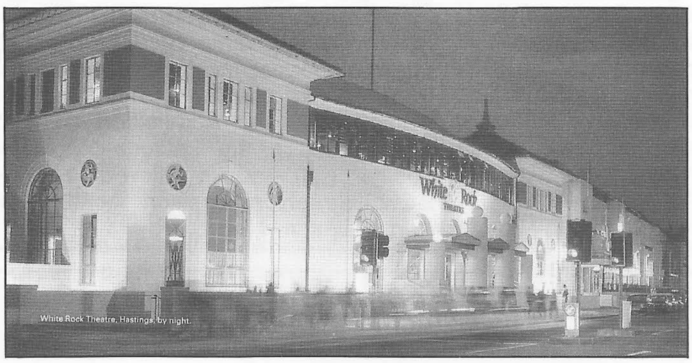
15-17 October 1993

Civic Reception: To be hosted by Hastings Borough Council at the Marina Pavilion at St Leonards-on-Sea on the evening of 15 October. Entertainment will include a special surprise guest.

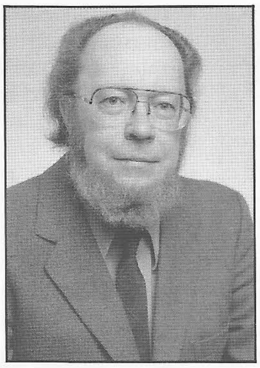
Opening Ceremony: To be performed by the Mayor of Hastings with a welcome to all participants.

Space Exhibition: To include as exhibitors Matra Marconi, BNSC and Logica.

White Rock Theatre, Hastings, by night.



Presentation: The BIS Space Achievement Medal will be presented to Dr W.I. McLaughlin for outstanding contributions to the advancement of astronautics over many years.



Dr W.I. McLaughlin.

Dr McLaughlin is Deputy Manager of Astrophysics and Fundamental Physics Preprojects at the Jet Propulsion Laboratory and was previously Manager of the Mission Profile and Sequencing Section. He also served as Project and Mission Engineering Manager for the Space Infrared Telescope Facility pre-project and as Flight Engineering Manager for Voyager's 1986 encounter with Uranus. He was also Mission Design Manager for the Infrared Astronomical Satellite.

His column "Space at JPL" has appeared regularly in ***Spaceflight*** since 1982.

Anniversary Dinner: To be held on Saturday 16 October at the Falaise Hall to mark the 60th Anniversary of the BIS. Guest speaker will be Professor Garry Hunt. Messages to the Society will be read out by Mr Martin Fry, Chairman of the 60th Anniversary Programme Committee.

Saturday Programme: Presentations will be given by speakers from NASA, ESA, JPL, BT, DRA and Inmarsat amongst others.

Armchair Interstellar Travel

A.T. Lawton

Evening Lecture to the Society, 3 March 1993

The Armchair Interstellar Traveller is just beginning to materialise, and is the descendant of the Armchair Interplanetary Traveller - a person who has been with us since Galileo first pointed his telescope at the Moon in 1610. The Interplanetary Traveller became a real commuter when Apollo 11 landed on the Moon in 1969.

His Interstellar Travelling counterpart may have to wait a few more centuries before interstellar commuting is a reality.

However, the Armchair Traveller has a very wide range of instruments at his command - and like Galileo's Telescope is opening up new vistas especially in the fields of young stars and infant planetary systems.

For example the James Clerk Maxwell milimetric radiometer has imaged a proto star (VLA 1623 in α Oph Area 'A') which is believed to be only 10,000 years old.

It is a condensing cloud 2000 AU in diameter with a mass 0.6 Solar, i.e. a prototype Red Dwarf.

Several proto Solar systems have been discovered in the Orion nebula using the Hubble Space Telescope. The star masses range from 1 to 3 Solar and the ages from about 2 to 5 million years. Over 40% of the star population are surrounded by ringed doughnuts of dust. These rings have estimated masses 15 x Jupiter thus providing adequate material for a Solar-type system with plenty left over for wastage. The doughnut is about 1000 AU across.

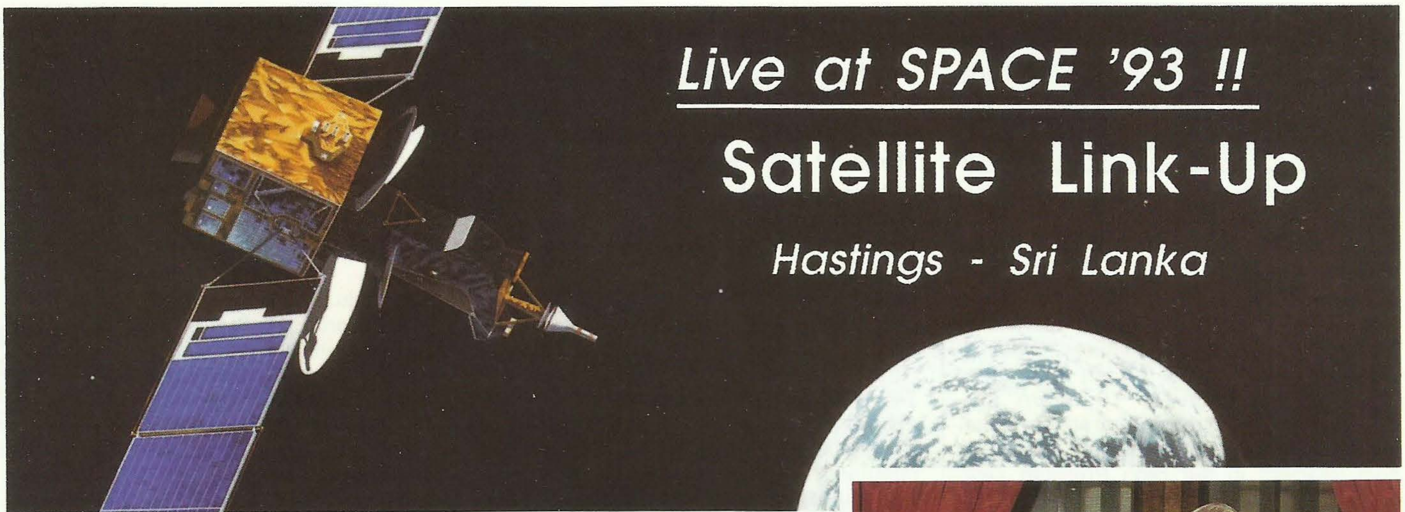
Another example chosen was β Pictoris where the doughnut of the dust has collapsed to a flat disc of less that 1 Earth mass. Here the expected collapse and wastage has occurred and almost certainly (but not yet proven) β Pictoris has a planetary system.

It is an A5 V main sequence star 53 light years distant. Previously such early Main Sequence stars were theorised as not likely to behave in this manner.

This star, and similar discoveries made by IRAS were to show a necessary revision. Another star heavily clothed with a dust ring is HD98800 which is 65 light years away in the southern constellation of The Crater. This radiates 10% of its total output in IR at 10 to 100μ.

This compares with β Pictoris which only radiates 0.24% at these wavelengths.

Starspot cycles similar to our Sun have also been recorded by the Armchair Traveller. The lecturer listed some 15 stars in our neighbourhood that were Solar-like in characteristics and showed magnetic storm cycles ranging from 3 to 30 years. Some stars, e.g. Tau Ceti, showed no cycle and may therefore be exhibiting a " Maunder Minimum" similar to that of our Sun from 1645 to 1715. Other stars show violent cycles 2 to 3 times more active that the Sun. Very recently our nearest neighbour Proxima Centauri (a known flare star Red Dwarf) has been shown to have a 41 day rotation period. This is almost twice as long as



Intelsat 6.

A.C. Clarke and Patrick Moore in Link-Up

By courtesy of Intelsat, Arthur C. Clarke, a former President of the Society and originator of the idea of geostationary orbits for communications satellites, in Sri Lanka, will be brought together with Patrick Moore and other participants at SPACE '93 for a session of open discussion via an Intelsat communications satellite.

Sunday Lunchtime Buffet: This will be provided, courtesy of British Telecom, to all participants in the Sussex Hall of the White Rock Theatre which will also be the venue for the satellite link-up.

Sunday Programme: Presentations will be given by speakers from BAe, AEA Technology, ESOC and Logica amongst others.

Close: At 5 pm on Sunday, 17 October.

Advance Registration: For information on the programme, accommodation and other arrangements, please contact The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Open to Members and Non-Members. Members enjoy a discount on rates.

A.C. Clarke with his long-standing friend Patrick Moore at a special reception in July 1992.

our own Sun's rotation period of 28 days. Also the starspots on Proxima are huge, amounting to 40% of the surface area on one side. Since this is very new material we do not know what cyclic periods Proxima has or the overall violence and activity during maximum and minimum phases.

Work has been done on refining the ecological limits of human-type life around solar-type stars. The upper limit is set by the distance where UV levels are so intense that water vapour is dissociated (for the Sun this is 0.95 AU).

The outer limit is set by the freezing point of CO_2 in the upper atmosphere (for the Sun this is 1.37 AU). Thus Earth is "just right" with Venus and Mars outside the limits and reflecting these limitations.

The speaker then discussed formation of planetary systems including the very strange ones that may exist around Pulsars.

It was concluded that since Earth was the only planet definitely known to have active life we should take very good care of it if we should ever hope to aspire to real Interstellar Travel.

NASA Presentation to the Society

STS-46 Mission Carried BIS Patch into Space

The STS-46 mission which successfully put into orbit Eureca, the first European retrievable carrier, also carried an "extra" item of payload in the form of a BIS "sew-on" patch. The return of the space-travelled patch to the Society's safe-keeping was occasioned by the presentation to it of a plaque from NASA and the STS-46 crew. The plaque was presented on March 13 by Claude Nicollier, who represented the European Space Agency as mission specialist on the STS-46 mission and was received on behalf of the Society by the Executive Secretary, Ms Shirley Jones.

BIS Fellow Claude Nicollier presents a special plaque to the Society on behalf of NASA and the crew of STS-46.

The inscription on the plaque reads:

> This BIS patch was flown aboard the Orbiter Atlantis, STS-46, July 31 - August 8, 1992, from which the EURECA-1 scientific research spacecraft was successfully deployed for retrieval during a later Shuttle mission, and the first Tethered Satellite System (TSS-1) was deployed and retrieved.

Launch Report

STS-55
Launch Pad Problems: Abort at T-3 s

The launch of STS-55, Columbia's 14th mission, was aborted at T-3 seconds on March 22, 1993 at 9:51 am.

Of the orbiter's three main liquid propellant engines only engines 1 and 2 successfully ignited. Engine 3 was shut down during its start sequence by the controlling computers when they sensed an overpressure in a purge area. The computers also shut down engines 1 and 2. Launch crews immediately went into a contingency safing mode to place the Space Shuttle and the Launch Complex 39A into a safe condition.

Columbia was moved to launch complex 39 A on February 7 and operations followed their normal sequence with a planned launch date in late February. However, on February 10 NASA announced that a question had arisen about the configuration of the turbine blade tip seal retainers in the High Pressure Oxidizer Turbopumps in Columbia's main engines. There are two versions of this seal - an older and a newer version. On the older versions there is a requirement to remove and inspect the retainers before each flight. The newer version does not have this requirement. Although all indications were that Columbia did have the newer version, a review of the paperwork did not conclusively show that the new version was in the STS-55 main engines' pumps.

As a precautionary measure, NASA managers elected to remove and replace the pumps on all three of Columbia's main engines. This removal and replacement was completed by February 18 and the next several days were spent securing and validating the installation of the new turbopumps. Subsequent inspections revealed that the removed turbopumps had indeed contained the newer version of the retainer.

On February 26 managers set March 14, 1993 as the new launch date. However, on the evening of March 2 a hydraulic hose in the vicinity of the main engine number 2 sprang a leak and hydraulic fluid was leaked into the engine area. All of Columbia's hydraulic hoses of that type were removed for inspection and spare hoses from Atlantis were inspected and then installed in Columbia. The failure in the hose that had leaked was traced to a change in its manufacturing process in 1977.

After reviewing data, managers set March 21 as the revised launch date. Although Columbia could have launched a day earlier, the Eastern Test Range, which controls and tracks launches, had a previously scheduled Delta rocket launch scheduled on the night of March 18. March 18 and 19 were, therefore, reserved for the Delta and a possible scrub. The test range could not reconfigure in time to support Columbia's launch on the 20th, so the 21st became the first available date.

On March 17 the STS-55 flight crew arrived from Houston and at 4:00 pm on the 18th launch crews began the STS-55 launch countdown. The launch was set for the morning of March 21, however, the Delta rocket was unable to launch on the evening of the 18th. The STS-55 count was halted at the T-35 hour point for 24 hours to allow the Delta a second shot on the 19th. Built-in-holds would bring the count to T-0 at 9:51 am on the 22nd.

As it turned out the Delta rocket also missed its March 19 opportunity for technical reasons and it was postponed several weeks. The launch countdown for STS-55 was resumed at midnight on the 19th and continued flawlessly throughout the weekend. A clear morning dawned on the 22nd and a routine launch count ensued throughout the built-in-holds and down to the engine start sequence at which point the abort was initiated by the on-board computers.

The reason for the abort was that the main engine did not fully ignite due to a liquid oxygen preburner check valve which apparently experienced an internal

SATELLITE DIGEST-252

Satellite Digest is our regular listing of world space launches. It is based upon a more detailed monthly satellite listing published by the Molniya Space Consultancy prepared by Phillip S. Clark.

Spacecraft	Int'l Desig.	Launch	Launch Site	Launch Vehicle	Mass kg	Orbital Epoch	Inclin. deg	Period min	Perigee km	Apogee km	Notes
Navstar 18	1993-007A	Feb 3.12	ER	Delta-2	1,881	Feb 14.77	54.85	717.93	20,008	20,355	[1]
Cosmos 2233	1993-008A	Feb 9.12	Plesetsk	Cosmos-B	825 ?	Feb 10.13	82.94	104.72	954	1,009	[2]
CDS 1	1993-009A	Feb 9.60	ER	Pegasus	14.5	Feb 10.28	24.97	100.01	727	791	[3]
SCD 1	1993-009B				115	Feb 9.66	24.97	99.97	725	790	[4]
Cosmos 2234	1993-010A	Feb 17.84	Tyuratam	Proton-4	1,300 ?	Feb 21.60	64.85	675.59	19,115	19,138	[5]
Cosmos 2235	1993-010B				1,300 ?	Feb 21.60	64.86	675.59	19,119	19,134	
Cosmos 2236	1993-010C				1,300 ?	Feb 21.60	64.85	675.58	19,117	19,135	
Asuka	1993-011A	Feb 20.08	Uchinoura	Mu-3S2	420	Feb 20.74	31.10	96.53	538	647	[6]
Progress-M 16	1993-012A	Feb 21.77	Tyuratam	Soyuz	7,250 ?	Feb 24.98	51.62	92.36	388	392	[7]

NOTES

[1] Ninth flight of a Block 2A Navstar satellite, also designated USA 88 by USSPACECOM. Mass quoted above includes propellant: dry mass is 930 kg. Actual launch time was 02.55 GMT.

[2] Tsikada-class military navigation satellite, co-planar with Cosmos 2142.

[3] Capabilities Demonstration Satellite (CDS, called OXP 1 by USSPACECOM) is a pathfinder satellite launched for Orbital Communications Corp, designed to demonstrate two-way message and data communications: inclusion aboard the launch was not announced until the satellite was in orbit. B-52/Pegasus took off from Cape Canaveral at 13.17 GMT and Pegasus was deployed at 14.30 GMT at an altitude of 13.25 km (43,500 ft)

[4] Brazilian Satelite de Coleta de Dados (SCD), designed and built by Brazil's civil space agency the Instituto Nacional de Pesquisas Espacials, acting as a communications satellite relaying data from Brazilian environmental monitoring stations, as well as carrying instruments to measure carbon dioxide and carbon monoxide levels in the atmosphere.

[5] Cosmos 2234-2236 are GLONASS navigation satellites, in the same orbital plane as Cosmos 2177-2179.

[6] Asuka (Astro-D prior to launch) is an X-ray satellite launched by ISAS. Actual launch time 02.00 GMT.

[7] Progress-M 16 is a freighter, carrying supplies to the Mir cosmonauts. Docked with the Mir Complex at the rear Kvant 1 port 1993 Feb 23 at 20.18 GMT. Orbit shown is after docking with the Mir Complex.

ADDITIONS AND UP-DATES

1986-017GZ This object is probably the Znamya solar reflector and, despite USSPACECOM cataloguing it as Mir debris, it

leak, allowing the purge system to be pressurised above the maximum of 50 psi. The on-board computers sensed the higher than allowed pressure in the line and terminated the main engine's ignition sequence. Several days were required to safe the orbiter on the pad, drain the external tank, obtain access to the aft engine compartment area and remove the suspect valve.

Roelof Schulling

STS-55 Main Engines to be Replaced

The investigating team concluded that the valve from the number 3 main engine failed to operate properly because of contamination that had been in the valve since it was manufactured. The team also determined that this condition could exist in other engines. A series of tests has been performed on Discovery and one suspect valve from one engine is being removed and replaced.

The decision was then taken that STS-56 would be the next mission. As part of the effort to have Columbia ready for a target date of April 24, all three main engines are being removed and will be replaced with those originally scheduled for use during the STS-57 mission with Space Shuttle Endeavour.

The STS-57 mission, which will involve the first flight of the Spacehab commercial payload and the retrieval of the European Space Agency's Eureca satellite, is now scheduled for a target launch date of May 18. The rest of the Space Shuttle missions planned for 1993 will stay in their planned order and schedule.

STS-56
Lift-Off Takes Heat Off 1993 Schedule

The second launch attempt of Discovery on April 8 was a rare night-time lift-off at the scheduled time of 1:29 am EDT after a spate of technical problems had beset NASA's 1993 flight schedule since early February with mounting disarray.

Jubilation greeted Discovery's successful launch. Two days previously, the first launch attempt had been aborted at T-11 seconds by the onboard computers when instrumentation on the liquid hydrogen high point bleed valve in the main propulsion system indicated off when it should have indicated on. Follow-up analysis showed the instrumentation was faulty and that the valve was in the proper configuration for launch.

Once in orbit, Discovery's Commander Kenneth Cameron fired the two manoeuvring engines to circularise the orbit at a height of 184 miles and inclined at 57 degrees to the equator. Joining Cameron on his second space flight are co-pilot Stephen Oswald, flight engineer Kenneth Cockrell and also Michael Foale and Ellen Ochoa.

Discovery's cargo bay contains a package of instruments called ATLAS (standing for Atmospheric Laboratory for Applications and Science) which will take an inventory of chemicals in the atmosphere and measure the Sun's radiation.

The primary work of the astronauts is to oversee the ATLAS mission keeping the shuttle properly positioned during science operations. The crew plans to work in two 12-hour shifts for around-the-clock operation of the Spacelab equipment. As part of the atmospheric studies, the crew also plans to deploy a small free-flying spacecraft, called Spartan, designed to collect information about solar winds during its 50-hour deployment in space. Also aboard the orbiter is a wide variety of space science and medical experiments that the astronauts plan to conduct throughout their eight-day flight. These include an electronic camera that automatically affixes photographed targets with geographic positioning data, and an amateur radio for communicating with schoolchildren and the general ham radio community. (See also 'ESA's STS-56 ATLAS-2 Experiments' overleaf).

Ariane-5 Booster Test

Initial analysis of the first static test at Kourou on 16 February of the P230 solid-propellant booster for ESA's Ariane-5 launcher has confirmed that all went well.

The booster, over 30 metres high and 3 metres in diameter was loaded with 237 metric tons of propellant - ten times the amount of any previous European booster - and burnt for 2 minutes and 16 seconds at full power. Analyzing all data (400,000 data points per second) will take several weeks.

should be classified as debris from the Progress-M 15 launch (1992-071, see below). Orbit: 1993 Feb 4.66, 51.62°, 92.39 minutes, 390 km, 393 km. Decayed from orbit 1993 Feb 5.

1992-018A Cosmos 2183 was de-orbited 1993 Feb 16. If the spacecraft returned a descent capsule then the nominal landing time would be about 1993 Feb 16.5. This is the longest lifetime of a Russian photoreconnaissance satellite to date.

1992-046A Soyuz-TM 15 with cosmonauts A Y Solovyov and S V Avdeyev undocked from the Mir Complex 1993 Feb 1.13 (03.00 GMT) and landed 100 km NW of Arkald 1993 Feb 1.16 (03.48 GMT).

1992-071A Progress-M 15 undocked from the Mir Complex 1993 Feb 4.03 (00.45 GMT). After undocking from the Mir Complex Progress-M 15 deployed mirror segments to give a solar reflector with a diameter of 20 metres. Experiments were then performed under the Znamya name to test the idea of using reflected Sun light to illuminate parts of the Earth's surface. After being jettisoned from Progress-M 15, the Znamya reflector was catalogued as 1986-017GZ (a piece of Mir debris), although a more accurate designator might be 1992-071C. Progress-M 15 was de-orbited 1993 Feb 7.

1992-086 USSPACECOM has issued the international designations and catalogue numbers for two objects deployed during the STS-53 mission. The payload - called "DOD-1" in NASA and other press releases and "USA 89" by USSPACECOM - is 1992-086B/22518 and a piece of debris from the mission is 1992-086C/22519. Orbital data for these objects are not available.

1992-088A USSPACECOM has now starting issuing accurate data for Cosmos 2224 after apparently tracking another object since soon after launch. Add the following orbit: 1993 Feb 2.38, 2.17°, 1,435.94 minutes, 35,697 km, 35,870 km. The satellite is operating over 12 °E.

1992-091A Cosmos 2225 disintegrated in orbit about 1993 Feb 18.75. The three previous satellites of this class (Cosmos 2031, Cosmos 2101 and Cosmos 2163) all disintegrated in orbit. USSPACECOM shows a decay date of 1993 Feb 18 for 1992-091A, indicating a rapid decay for the main object which remained after the break-up.

1993-006A Add the operational orbit for Cosmos 2232: 1993 Jan 30.66, 62.80°, 717.98 minutes, 596 km, 39,769 km.

International Space Report

Half-Price Space Station

WASHINGTON - Under orders from President Clintón, NASA officials are going back to the drawing boards to develop new plans for a cheaper, more efficient manned space station. The redesign will plan to put a space station into orbit by the end of the decade at perhaps half the $31 billion price tag for space station Freedom. NASA administrator Daniel S. Goldin announced that a radical reduction in the scope of the space station design must be completed by June 1. The redesign team is headed by Joe Shea, a NASA veteran of the Apollo era. The size of the team is to be limited to "no more than 30 or 35 NASA people", plus international representatives and outside consultants. Three options are to be presented to the administration, which expects that the quicker and cheaper design of the space station will be a forerunner of wholesale changes in its programmes.

UN Expands Satellite Services

UNITED NATIONS, NY - UN Secretary General Boutros Boutros-Ghali and Intelsat Director General and Chief Executive Officer Irving Goldstein have signed an agreement to provide the United Nations expanded use of the global Intelsat system. This expansion enables the UN to increase its satellite communications capabilities for disaster mitigation/prevention and relief communications services, as well as communications to support the developmental and institution-building efforts of various UN specialised agencies.

Today, the UN network, based in New York, operates via five Intelsat leases. Earth stations used in the network range in size from 11 metres, at the New York hub, to 1.8 metre transportable antennas that give the UN flexibility to move quickly to meet changing emergency requirements.

INTO THE NEXT MILLENNIUM

An invitation to:

"SHARE OUR IDEAS FOR THE FURTHER EXPLOITATION OF SPACE, THE DEVELOPMENT OF TECHNOLOGY AND OF THE SOCIETY ITSELF"

Does the above look or sound familiar? The avid reader will recognise the words of Mr Martin Fry as detailed in Society News, November 1992.

So why repeat them here? Well Martin went on to say:

"WE INVITE ALL TO SHARE WITH US IDEAS AND TO CONTRIBUTE TO THEIR REALISATION IN THE YEARS AHEAD"

Thus the Society needs your involvement in meeting this challenge. A Council Advisory Committee on Space Policy and Technology has been formed in this the 60th year of the Society to develop short medium and long term plans for the Council to use as blueprints for its strategy in addressing Space Policy and Technology Exploitation.

Martin Fry, as chairman of the committee would welcome your thoughts and proposals for the consideration in the committee. The committee will undertake to evaluate all concepts proposed and critically assess their suitability. In making your submission to the Society known to Martin please assist the committee by detailing the commitments that you can provide in developing the proposals further.

So if you wish to contribute in assisting the committee with its task please write to Martin Fry care of the Society Headquarters.

ESA Implements 'Granada' Decisions

Go-Ahead on Environment and Telecommunications
Crewed Space Flight Under Review

The European Space Agency's Council has unanimously approved the start-up of programmes decided on by the Council meeting at ministerial level at Granada in November 1992.

These programmes are the environmental programmes, with the ENVISAT missions (for observation of the Earth and its environment) and METOP missions (in meteorology and climatology), and the telecommunications programme, which includes the data relay and technology mission (DRTM); this has two elements - the ARTEMIS technology missions and the DRS data relay system, together with work on the Hermes programme.

Where crewed space stations are concerned, it was agreed to look again at the content of these programmes between now and the end of the year, so as to adapt if necessary to what happens with the international space station Freedom. Additional contract authority was however unblocked, to safeguard the work needed for continuing, in 1993, the programmes for the Columbus attached laboratory, the polar platform and the Mir flights that are part of the precursor flights.

Following the meeting, ESA's Director General Jean-Marie Luton said he was optimistic about the future of the European space programmes: "The ESA member countries have clearly shown their will to carry on with the development of ambitious programmes, while taking account of the political changes going on in Europe and round the world".

ESA's STS-56 ATLAS-2 Experiments

PARIS - ESA sees its participation in the second flight of the "Atmospheric Laboratory for Applications and Science", ATLAS-2, as a further step in preparing for utilisation of the Columbus Attached Laboratory.

Three out of the seven instruments have been developed by European scientific institutes. Two instruments, SOLCON and SOLSPEC, will accurately measure the "solar constant" and the spectral distribution of this radiation. Such knowledge matters not only for a better understanding of the Sun, but also for improving numerical models of climate and climate change. SOLCON was developed under Dr Dominique Crommelynck of the Royal Meteorological Institute of Brussels, Belgium. SOLSPEC was developed under Dr Gerard Thuillier of the CNRS, Verrieres le Buisson, France.

One of the instruments will be fully remote-controlled by scientists from a laboratory in Belgium, via telecommunications links to the Shuttle, and the data of another will be transmitted to Belgium in real time to follow the results obtained.

The third European instrument, called MAS (Millimeter Wave Atmospheric Sounder) will measure the absorption spectra of water vapour and trace gases in the upper atmosphere. The measurement programme includes most notably ozone and chlorine monoxide, which plays an important role in the ozone cycle. MAS was developed under Dr Gerd Hartmann of the Max-Planck-Institute für Aeronomy, Lindau, Germany.

The ATLAS missions are enabling ESA to gain valuable experience for the future utilisation of its Columbus Attached Laboratory. They complement a number of ESA satellites currently under development, such as SOHO, ERS-2 and ENVISAT-1.

India Increases Space Budget

INDIA - Despite serious economic problems and an urgent need for resources for socio-economic development, India's latest budget, announced on 27 February 1993, has a 40% increase in allotments to the Department of Space for a record total of Rs7,180.5 million.

About Rs1,600 million is to cover the cost of development of INSAT-2B communications-TV-meteorological satellites to be launched early in 1994. INSAT-2A, currently operational, is a fully indigenous design and has a very high indigenous content, including the VHRR (Very High Resolution Radiometer). It has worked faultlessly since launch.

Development of the PSLV (Polar Satellite Launch Vehicle) and the GSLV (Geosynchronous Satellite Launch Vehicle) continues and the budget has allotted Rs300 million more than last year for their continuing development.

Hormuz P. Mama

UK Firm Wins Order from India

RACAL-REDAC (UK) Limited, Reading, Berkshire - The Indian Space Research Organisation (ISRO) has announced that it will be using Racal-Redac's Expert Series of Electronic Design Automation (EDA) tools for the design of electronic modules in its INSAT-2 satellite programme which comprises a series of second-generation, multi-purpose, geostationary satellites for providing operational services to India. These satellites will be used in a number of applications, including telecommunications, television broadcasting and meteorology. All the major branches of activity at ISRO - such as satellite and ground control electronics and payload and image processing systems - have been using Racal-Redac's design tools for over five years.

India's first satellite, INSAT-2A was launched from French Guiana, using the European Space Agency's Ariane rocket in July 1992. Of the 200+ printed circuit boards (PCBs) which the satellite contains, over 95 per cent were designed using Racal-Redac's software.

Racal-Redac provides a full range of workstation and PC-based EDA tools which are used in the design of the complex, high speed, high density integrated circuits and PCBs used in today's hi-tech industries. They embody a right-first-time methodology, closing the traditional gap between design, verification, implementation and manufacturing, and eliminate the need for multiple physical prototyping.

Racal-Redac is one of the world's leading EDA software vendors and is the largest electronic design company in Europe. Racal-Redac's design tools are used by 47 of the world's top 50 electronic companies, as listed in the Electronic Business top 100.

Budget Increase for Launch Site

CAYENNE, French Guiana - France's National Space Agency (CNES) has increased by 15 per cent its participation in 1993 financing of its launch centre in French Guiana. 200 million francs ($37 million) would be available for upgrading and investments at the Guiana Space Centre (CSG) in Kourou, French Guiana. The new funds will be used primarily to upgrade tracking equipment such as radar and telemetry.

UK Space Budget Problems

BRISTOL - Edward Leigh MP, the UK Space Minister, admitted at a press conference in Bristol on 21 March that the UK space budget was in "difficulties" because of the currency fluctuations of sterling.

The majority of the UK's small space budget goes to support ESA and its projects. About half this money stays as pounds sterling to pay British contractors to ESA, the other half supports ESA itself and is converted into Francs, Guilders, Deutschmarks etc. to pay for the various ESA centres. If a member state's currency reduces in value relative to other European currencies then more national money is required to maintain its support to ESA. This is done by a formal method known as "Retroactive Adjustments" and countries like Britain, which do not have major ESA sites returning money to it, are especially vulnerable to such currency fluctuations. So it is not surprising that the recent large devaluation of the pound looks set to have a very damaging effect on the UK space industry.

In discussing the problem Mr Leigh said, "I ensured in our discussions with the DTI that we were able to maintain our contribution to ESA. Quite frankly we have to maintain it at our current level if we are to remain prime contractors for Earth observation".

The Minister made it clear where the book balancing will occur. "If anything has to take the strain it is our national space budget. There is no doubt about that because I simply cannot negotiate with the Treasury an increase in the national space budget to take into account these currency fluctuations. So sadly there will have to be some cuts, but I cannot say where they will fall or how much they will be". He added, "It is of great concern to me. I think it would be an enormous shame if, because of the necessity of maintaining our contribution to the European Space Agency, our national work was devastated".

Mark Hempsell

is interested to hear from you. Let the Chairman of the BIS Programme Committee know, care of the Society's HQ, and he will look at ways of helping you in finding potential visiting speakers for meetings at your venue on behalf of the BIS. If this approach proves popular there may be scope for assistance outside of the UK as well.

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SKYL

A Key Element of a Future

It is now over ten years since design work was begun on the engines which led to the British Aerospace (BAe) HOTOL spaceplane project and which in turn triggered a world-wide flurry of spaceplane research. While other nations have continued their work, the UK project, which was by far the most practical commercial concept, followed a route of slow starvation by lack of finance and government vision. BAe, to its credit, has continued to develop its ideas but it has had to step back to an interim technology vehicle which does not include the advanced engines needed for single stage to orbit (SSTO) operations [1].

Rolls Royce's acquisition of the HOTOL powerplant patents in April 1988 and its official notification to ESA of its intention to withdraw from spaceplane work in January 1989 meant that a hard won technology lead on the rest of the world was in danger of being lost. It was against this background that Reaction Engines Ltd was formed.

The SKYLON spaceplane.

Introduction

Reaction Engines Ltd is a propulsion engineering company with the main objective of developing engines for highly economic space transportation. The company was formed in August 1989, and was developed from Alan Bond's consultancy "Reaction Engines", which played a significant role in determining the design of the HOTOL engines. Reaction Engines Ltd has drawn together a small team of propulsion expertise within the UK whose experience ranges from the earliest days of British post-war rocketry including Blue Streak, Black Knight, Black Arrow and the experimental Lox/hydrogen programme to modern gas turbines and the HOTOL studies.

Currently the company is engaged in the design of SABRE, a very advanced engine to propel the SKYLON spaceplane, which is also a Reaction Engines design. These projects are the main theme of the present paper.

Another project, still in the gestation phase, is for an ultra high chamber pressure Lox/hydrogen rocket engine for upper stage and inter-orbital transport operations. Such a vehicle is essential to complement the capabilities of an SSTO spaceplane.

Why Build a Spaceplane?

Over the past decade numerous spaceplane studies have been carried out in many countries, including HOTOL, NASP, Sänger, Delta Clipper and other less well known vehicles. These studies have resulted in an extraordinary range of configurations due to different perceptions of the role of a spaceplane. Reasons which have been put forward for pursuing spaceplane development include national prestige, military capability, technology advancement, industrial stimulus, motivating the young, development of supersonic transport derivatives, manned space flight capability and finally, supporting space station operations.

Some of these demand performance capability beyond that of present expendable launch systems. For example, piloted vehicles require life support systems, additional payload capability and stringent flight-worthiness certification increasing development costs by approximately 50%. Another instance is the excessive flexibility imposed on NASP, necessitating the expensive development of a technically demanding scramjet propulsion system.

In our view the above arguments miss the reason for designing a new transport system. The object of the new system should be to exploit space in its own right by overcoming the cost and operational disadvantages of the expendable launcher, which in other respects provides a satisfactory service. Expendable launchers are derivatives of ballistic missile technology and because they are only used once, the launch costs are high typically \$100M/launch. This high launch cost in turn forces satellite manufacturers to adopt conservative design philosophies since the cost of replacing a faulty satellite is so high. This approach in turn increases the satellite cost and reduces the rate at which new technology is adopted. Multistage, vertically launched rockets are labour intensive and time consuming to prepare, imposing a modest limit on the maximum launch rate that can be achieved from a launch site. Finally due to the lack of abort options the reliability is relatively low (about 95%), which impacts on the insurance costs.

Thus due to the limitations of the transport system, the actual traffic to orbit is very low when compared with the rest of terrestrial transport. As a result, very few areas of space activity are genuinely economic, the exception being communication satellites which cost about 2% of the revenue they generate in their design lifetime. The correction of this situation is the immediate justification for a spaceplane.

There is, however, an even more important long term reason for beginning spaceplane development now. To date, civil space programmes have been characterised by high risk, expensive, glamorous, high technology extravaganzas, such as the Apollo programme, that leave behind

...LON: ...Space Transportation System

BY RICHARD VARVILL
Technical Director, Reaction Engines Ltd
and
ALAN BOND
Managing Director, Reaction Engines Ltd

Reaction Engines Ltd

zero long term infrastructure and in the public's eyes offer very little payback into society. This mentality continues today with recommendations to build large space stations, return to the Moon and conduct manned voyages to Mars. It is not surprising that governments are reluctant to pour money into such projects when they are justified by the relatively weak argument outlined above, especially when set against a world beset with industrial recession and environmental problems. Yet it is space which offers the greatest potential for solving these problems.

The outstanding features of human history over the last few centuries are population growth and technology advancement. The material standard of living per capita has risen continuously due to the application of technology enabling the large scale exploitation of the planet's resources. The success of this activity can be measured by the fact that the world population has risen to 5.6 billion and is set to exceed 10 billion early in the next century. However, this growth pattern cannot continue for much longer due to the limited accessible resources of a finite planet and the accumulation of waste and industrial pollution. World dynamics modelling, first carried out by Forrester [2], highlighted with startling clarity the approach of a world crisis in approximately 2050 followed by a collapse in population and standard of living if present social policies are allowed to continue. In addition, early models showed the intractable nature of the problem with various approaches such as population control and recycling of basic materials merely delaying the final collapse rather than representing long term solutions. These conclusions have now been confirmed by many workers of wide ranging political persuasions.

The underlying problems behind the "limits to growth" dilemma are due entirely to the finite size of the Earth restricting the availability of raw materials, cheap energy and land area to support a growing population. However, as first pointed out in a paper by Martin [3], previous solutions had attempted to solve the problem internally, ignoring the fact that the Earth forms a part of the far larger Solar System. The resources of the Solar System far exceed those of Earth in terms of volume, raw materials and power. The Sun is a virtually inexhaustible source of clean energy, which could be readily exploited by power satellites with existing technology. The enormous volume of the Solar System is an "unfillable" sink for waste materials and industrial effluent. Finally, the bodies of the Solar System contain far more winnable minerals than exist on the Earth. For example, the volume of material contained in the asteroid, Ceres, is equal to the outer kilometre of the entire Earth's crust. By exploiting the minerals present in the Moon, and subsequently those of the asteroid belt as well, mankind could solve the material supply problem permanently and move most of the pollution creation off the Earth.

Space industrialisation represents a major contribution to a long term solution to the problems of population growth, pollution and material standard of living. However it cannot commence until the world has access to a low cost flexible launch system. in the near term, such a system would simply replace current expendable launchers whilst in the medium term the vehicle would help to create and service expanding cis-lunar operations. In the more distant future spaceplanes would be the first element of a Solar System transportation infrastructure, enabling the exploitation of extraterrestrial energy and mineral resources.

Clearly all of this cannot be developed "overnight" and, as in the case of air transport, several generations of development on operational machines will be needed to pave the way. We must start now if suitable machines are to be operating in the final quarter of the next century.

What Should a Spaceplane be Like?

If a future launch vehicle is to achieve a low specific launch cost ($/kg) and be genuinely easy to operate it must meet the following criteria, most of which are common to other successful forms of transport:

- The vehicle should consist of only a single stage in order to reduce the development and operational cost relative to multistage vehicles. Cost models developed at BAe by Bob Parkinson have clearly demonstrated that two stage vehicles are approximately 50% more expensive to develop and have twice the recurring launch costs due to the more complex operational procedures. The simplified ground operations of a single stage launcher will reduce the turnaround times thereby increasing the vehicle utilisation rate and hence load factor.

- The vehicle should be as reusable as possible. Disposable boosters and other flight critical hardware have an inordinate effect on the operating cost of an SSTO vehicle due to the associated quality assurance operations. By amortising the vehicle production cost over 200-500 flights, the specific launch cost is reduced by a factor of at least 10 when compared with expendable launchers. Whilst this level of reusability is modest when compared

with modern air transport, it is considered to represent a sensible target for a first generation spaceplane. Second generation spaceplanes will probably be designed for thousands of reuses, in which case the operating cost will eventually approach the recurring cost.

- In the first instance, the vehicle should be unpiloted (computer controlled) since qualifying a man rated vehicle increases the development cost by approximately 50%. The initial batch of vehicles would take over the satellite launching role of today's expendable boosters, a relatively simple task that can be adequately handled by current computing technology. As operational experience is gained and reliability improves, versions can then be built to safely transport people to space stations etc. By designing the vehicle with a maximum of onboard autonomy (guidance, navigation and control), the size and complexity of the mission control centre can be cut down considerably. Clearly it is undesirable to maintain the current mission control procedures when many flights per day are contemplated as a realistic design goal.

- To minimise turnaround time and cost, the vehicle should have simple launch and recovery procedures. By designing the vehicle with aircraft-style fuelling and checkout, the ground crew can be reduced to 200 to 250 people rather than the thousands required today. The launch facility should be as simple as possible to minimise the cost of replacement in the event of a launch pad explosion. In this respect, horizontal take-off vehicles capable of being rolled out to the launch area on their own undercarriage are at an advantage when compared with the elaborate launch gantries necessary to support vertical take-off rockets. Similarly, a winged landing on a conventional undercarriage, as demonstrated by the Shuttle, makes for simple inexpensive recovery.

- In the event of complete propulsion system shutdown due to a common fault, such as a failure in the fuel or control systems, the vehicle must be capable of an aborted landing at any time during the ascent. This requirement dictates that the vehicle must be controllable in unpowered flight with adequate aerodynamic performance to allow a "deadstick" landing. Full mission abort capability increases vehicle reliability and will therefore reduce insurance costs.

- The vehicle systems must be designed for minimal maintenance between flights. This Implies reliable engines and a robust thermal protection system. Clearly one would aim to achieve aircraft-style maintenance procedures where a minimal visual check of the aircraft is accompanied by lubricant, hydraulics and tyre checks.

- The spaceplane is a new transport element and it needs to interface with other elements if it is to become part of an efficient transport system. We envisage that the spaceplane payload would be "containerised" in a rugged container, into which the payload would be Installed at its origin. This container would be transported by dedicated aircraft to an appropriate spaceport where it would be transferred to a spaceplane. The container would weigh perhaps 10% of the payload and be "dirty outside" and "clean inside". The spaceplane would only maintain normal cleanliness standards in the payload bay. Since the containers would comply to agreed standards such as overall dimensions and mounting features, payload "integration" would become obsolete with massive simplification to the prelaunch activities. It is worth remembering that ship containerisation revolutionised maritime transport; loading ships used to take weeks whilst it can now be achieved overnight.

- Finally, environmentally benign propellants should be employed (lox/hydrogen) if serious atmospheric pollution is to be avoided. Similarly, the launcher must not exacerbate the orbital debris problem.

If all of these requirements are met then an efficient, utilitarian and cheap transport system should result. In principle, there would be nothing to prevent regular access to space on the scale necessary to begin space industrialisation (e.g. globally several hundred launches per day from five equatorial launch sites). While this may sound like science fiction when compared with today's activity, it is very modest by air transport standards. For example, in 1990 civil aviation carried 130 billion ton-km of payload. Heathrow alone handles approximately 300,000 traffic movements, 35 million passengers and 700,000 tons of air cargo per annum.

Technical Considerations

Clearly when attempting to meet any engineering specification, it makes sense to incorporate as much current technology and previous experience as possible. The SKYLON design, therefore, represents a development of aircraft and rocket technology, while the SABRE engine represents a development of gas turbine and rocket engine technology. Such an approach will minimise the technical risk and reduce the development costs.

This philosophy contrasts strongly with the NASP programme where the vehicle is operated in an exceptionally severe flight regime (Mach 15 at high dynamic pressure). While this latter approach will result in maximum technology acquisition, it will not necessarily result in a successful or economic transport system.

When considering the general features of the SKYLON/SABRE system several points were borne in mind:

- The engine must require a trajectory which is benign to the airframe in terms of aerodynamic heating and loading enabling a lightweight airframe to be constructed with a passively cooled aeroshell.

- The engine must be capable of open test bed operation to minimise development costs. This point counts against ramjets and scramjets which require exceptionally expensive wind tunnel facilities to simulate real flight conditions. For example, the NASP programme has had to place heavy reliance on CFD codes and flight test vehicles.

- The vehicle and engine should employ extant or near term materials technology and not be dependant on the development of a speculative material to counter the deficiencies of a poor design.

Generally speaking, lightweight structures have been achieved in SKYLON and SABRE by placing emphasis on novel designs and developments in manufacturing technology.

The SKYLON Vehicle

The SKYLON/SABRE concept developed from a design review of the British Aerospace HOTOL/RB545 vehicle. SKYLON is designed to launch a 10 tonne payload into a 300 km due east orbit from Kourou (or any other near equatorial launch site). The payload into a 460 km 28.5 degree (space station) orbit is 7.7 tonnes. The fuselage contains a central payload bay and lox tankage plus two hydrogen tanks occupying the tapered ends of the fuselage. The swept delta wing is located roughly midway along the fuselage and carries an integrated intake/engine nacelle on each wingtip. Aerodynamic control is achieved by active foreplanes in pitch, an active forward fin in yaw and ailerons in roll. Thrust vector control takes over progressively during the rocket ascent by collective gimballing of the rocket

chambers within each nacelle. Figure 1 shows the vehicle layout.

SKYLON's configuration results In an efficient resolution of various technical compromises that seriously eroded the payload performance of HOTOL. Consequently, SKYLON can launch approximately twice the payload mass Into orbit for the same take-off mass.

The first problem which had to be addressed was the centre of pressure shift encountered by all flying vehicles having a wide Mach number range. As the vehicle accelerates from rest the centre of pressure (CP) initially tracks rearwards due to the transonic wing CP shift. Beyond Mach 1, the CP moves forward due to a changing balance between forebody and wing lift. On SKYLON, the centre of gravity (CG) travel Is matched to the CP travel by scheduling the fuel usage from the front and rear hydrogen tanks. By this means the need for propellant transfer between tanks, such as that employed on Concorde, is avoided.

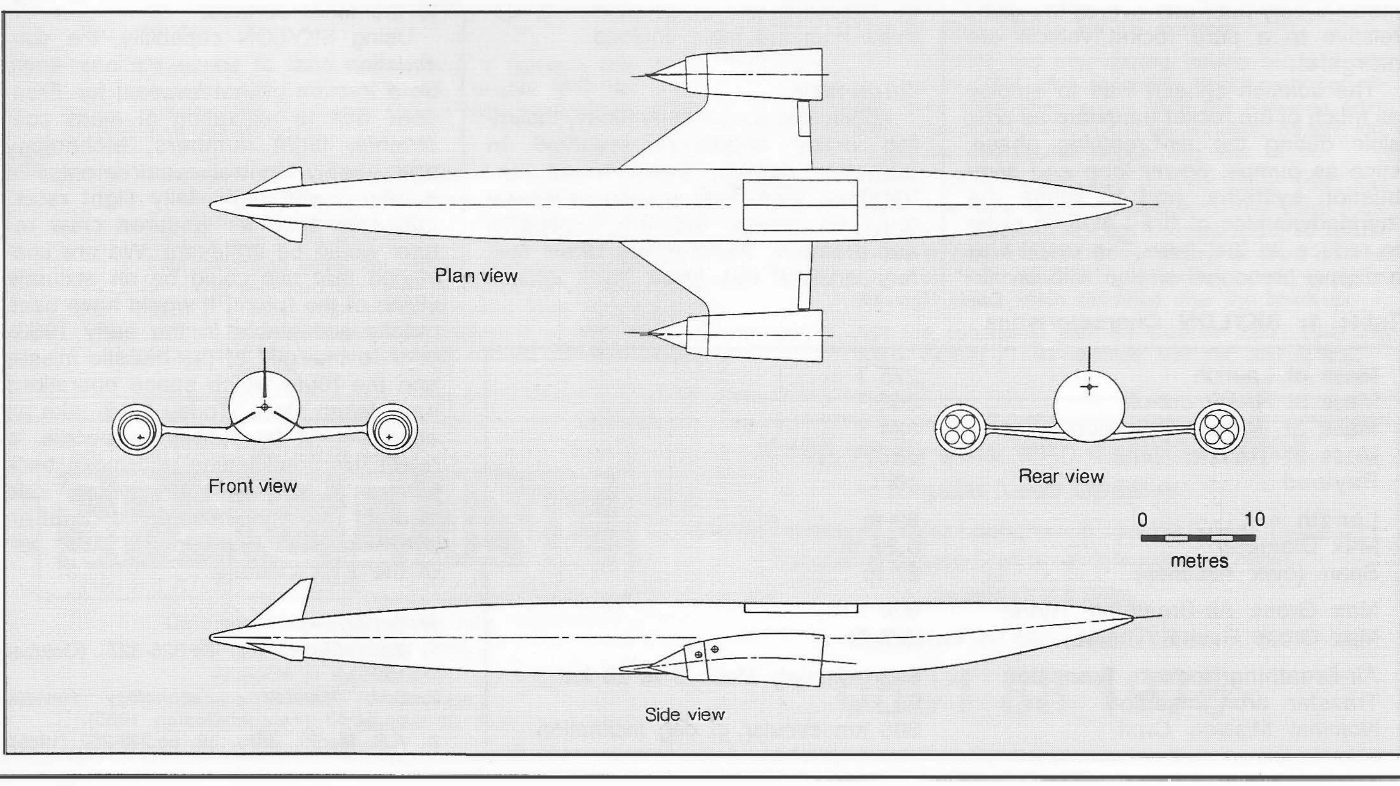
Residual CG/CP mismatches are trimmed out by active foreplanes which, due to their large moment arm about the CG, result in negligible trim drag penalties. Additionally, by employing the foreplanes to control the vehicle in pitch rather than flaperons on the wing trailing edge, considerable savings in actuation and power supply masses result. Savings are also made in wing weight due to the reduced torsional moments. By locating the engine nacelles on the wingtips rather than on the fuselage base, considerable freedom is gained to position the dry centre of gravity close to the hypersonic CP thereby achieving a trimmable vehicle during re-entry.

The SKYLON configuration results In an extremely efficient structural design. Due to the reduced overhang and mass of each hydrogen tank, the fuselage inertial bending moments are reduced to approximately 25% of the values existing in the HOTOL fuselage. The removal of the Intake from under the fuselage results in load paths and stowage of the main undercarriage similar to conventional aircraft, whilst the integrated intake/engine nacelles minimise the intake mass due to the axlsymmetric cross-section and the elimination of unnecessary ducting.

The SKYLON configuration has less drag than the HOTOL airframe due to the elimination of the fuselage base area and the Increased fuselage fineness ratio. The drag reduction has an especially favourable impact as the vehicle accelerates through the transonic region, when vehicle acceleration can fall to a small value due to Inadequate thrust over drag, resulting in excessive fuel burn. However, SKYLON can maintain axial accelerations of greater than 1.65 m/s^2 in this regime. One of the most unsatisfactory features of HOTOL was the need to develop a high speed (300 knots) launch trolley to save the weight of a take-off undercarriage. Due to the fuel savings of the SABRE engine, it has been possible to replace this feature with an integrated rocket assisted take-off unit in SKYLON. Such systems have a good precedent in the 1950s Cruise missiles which employed expandable RATOs in order to achieve a 'zero length launch'. Using this system SKYLON would become airborne after only 7 seconds and in a distance of 650 metres.

As a final observation of the SKYLON configuration, it is worth noting that the technical literature abounds with articles placing great importance on the need to Integrate normally separate components into a single functional unit when designing an SSTO launcher. For example, blended wing/body designs are common with the forebodies serving as Intake compression surfaces and the aftbodies forming part of the exhaust nozzle. This approach is taken to a limit in the design of NASP. However, it is our opinion that his methodology is better suited to a vehicle designed to cruise at a fixed Mach number such as a supersonic transport. An SSTO launcher has to operate effectively over a range of Mach numbers and it is difficult to arrange sufficient flexibility in the design If the major components are tied together. Also a blended wing/body/engine design does not lend Itself to efficient structural design. Conversely, the SKYLON configuration retains separately identifiable components to perform the roles of lift, propulsion and fuel storage allowing each component to be individually optimised. This approach results in a vehicle that may have a lower aerodynamic performance at a single point but achieves an extremely lightweight structure. Since launchers must continuously accelerate up to orbital velocity, the optimum overall performance is achieved by sacrificing air-breathing fuel efficiency in the interests of saving weight. Table 1 presents some of the leading parameters of the SKYLON vehicle.

Fig. 1 SKYLON Configuration A4. *Reaction Engines Ltd*



The SABRE Engine

Many studies performed world-wide since the 1960s have shown that rocket powered ballistic SSTO vehicles are technically feasible, but have low re-entry cross range and marginal payload fractions.

Because of the exponential dependence of the rocket mass ratio on the mission velocity requirement, it is tempting to reduce the mission velocity increment in the rocket phase by the use of air-breathing assistance early in the trajectory. Studies using gas turbines or air augmented rockets and ramjet combinations have, however, shown disappointing results due to the extra hardware mass and vehicle drag absorbing the gains in propulsive efficiency. This route therefore usually reverts to a two stage vehicle concept with an air-breathing powered aircraft first stage and a rocket upper stage. The TSTO loses the operational attractiveness of the SSTO concept in the process and incurs the extra development cost of two different vehicles.

An alternative approach is to attempt to integrate air-breathing and rocket engine components into a single set of hardware employing shared components in each mode, the so called hybrid engine approach. Most attempts have concentrated on the air-breather and added the rocket function as an extra capability. This results in low rocket performance, again destroying the potential gains. The liquid-air-cycle engine (LACE) maintains high rocket performance and employs a simple air-breathing device with low mass in which the liquid hydrogen fuel liquefies the intake air in order that it may be pumped into the rocket chamber. However, its specific fuel consumption in air-breathing mode is very poor and overall the gains relative to a pure rocket vehicle are marginal.

The solution chosen was to employ as much of the rocket hardware as possible during the air-breathing phase, such as pumps, power loop and combustion systems, and to refine the thermodynamics of the LACE in order to reduce its fuel flow. The result was a deeply precooled engine with an air-breathing mode specific impulse about twice that of a LACE. No liquid phase is encountered in the cycle other than water moisture which has to be controlled to prevent it choking the precooler as it freezes. Reaction Engines' current engine, designed around the above concepts, is the SABRE (Synergetic Air-Breathing and Rocket Engine). The RB545 in HOTOL was a simple variant of this type of engine whilst the SABRE has traded simplicity for better performance. The SABRE engine differs from the RB545 in that the air compressors are driven by a separate power loop rather than employing the work capacity of the hydrogen stream directly.

The SABRE performs its start transient in rocket mode, transferring to air-breathing mode immediately that mainstage combustion is initiated. The engine operates in air-breathing mode during an optimum ascent to an altitude of 26 km at Mach 5. The vehicle then performs a programmed dive followed by a pull up in order to maximise the climb angle at the start of the rocket ascent. At this point, the engine transitions to rocket mode, while continuing to operate, in order to complete the ascent to transfer orbit injection at about 80 km. The air inlets are closed on transition to rocket operation and remain closed throughout the rest of the mission including re-entry.

In order to match the captured airflow to the engine demand, a bypass duct is included with a reheat burner. This is in effect a subsonic combustion ramjet which operates in parallel with the main engines. The thrust of this system peaks around transonic flight and contributes considerably to the vehicle performance for this reason. At higher Mach numbers, this system is ineffective and all propulsion is derived from the main engines.

Summary

Within the space community, including many engineers involved in launcher design, there is an entrenched view that access to space must be forever difficult, expensive and dramatic. Whilst in the 1950s military 'artillery' has given quick access to space, its legacy is a closed minded attitude towards launch vehicle design and a public view of space as a place of zero value except as a playground for scientists and technologists.

Yet those who fly by Concorde enter a hostile environment for a few hours, and are transported by a vehicle having spaceplane complexity to their destination without months of checkout and without thousands of mission-related crew. How is this possible when 50 years ago the propulsion, aerodynamics and electronics which make Concorde possible were unknown? Indeed, those few decades ago, engineers were still contemplating subsonic staged aircraft for long-range terrestrial missions!

Clearly successful transportation needs to meet customer requirements. There is no edict which says space is forever beyond reach. It is we who are keeping it that way by the use of proven but inadequate technology. Today, we can contemplate vehicles capable of providing access to space as easily as Concorde services transport between London and Washington. With such a vehicle, it is possible to consider sales of vehicles to many nations around the world with an interest in space, as is the case with aircraft at present. Space traffic need not be 5 per month, but could reach hundreds per day of multinational flights operating from international spaceports, mainly near the equator.

Reaction Engines Ltd has ongoing studies of a cis-lunar transportation infrastructure and its economic evolution. This involves transfer stages, toroidal space stations with artificial gravity, propellant transporters and orbit transfer vehicles spanning LEO to the lunar surface.

Using SKYLON capability, the construction cost of space stations would be a fraction of that forecast for 'Freedom' due to relaxation of mass constraints, flight numbers, technology and quality control requirements. In addition, with high daily flight rates, concepts such as 'assured crew return' would be irrelevant. We are convinced that this could be an accurate vision of the future. It would have been readily acceptable in the early 1950s prior to the 'gift' of the ballistic missile and the route which space operations have taken since. Today it will take an effort of will by perceptive people to reject this conditioning and move back towards a true transport system able to meet the frightening demands of an over-populated Earth in the latter half of the 21st Century.

Table 1: SKYLON Characteristics

Mass at Launch	275 T
Mass at RATO cut-off	262 T
Mass at Rocket Transition	224 T
Mass at Transfer Orbit	55.7 T
Payload	10 T
Length	82 m
Max Diameter	6.25 m
Span (over nacelles)	27 m
Max Gross Air-Breathing Thrust	300 T
Max Gross Rocket Thrust	300 T
Air-Breathing/Rocket Transition	approximately Mach 5 at 26 km
Transfer orbit Insertion	80 km
Nominal Mission Orbit	300 km circular, 5 deg inclination

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FESTIP

(Future European Space Transportation Investigations Programme)

esa

A Long-Distance Look into the Future

1995-96 for First Decisions on the Future of European Space Transportation

Speaking of future space transportation, ESA's Director-General indicated his enthusiasm for the Agency's FESTIP programme to a meeting of the UK Parliamentary Space Committee last December. But, what is ESA's FESTIP and what are its present aims? *Norman Longdon* outlines the timescales and technologies associated with this programme.

BY NORMAN LONGDON
ESTEC/ESA

The present political and economic climate around the world is not conducive to all aspects of space, and new launchers are included in that category. Europe is extremely well placed with Ariane 4 holding the strongest single market position and Ariane 5 well on its way with excellent results from its first major booster firing tests. There might be a case for saying "isn't that enough?", but science and technology have never accepted such a notion.

Looking further ahead, Ariane 5 has a long-term future from the start of its operational phase in the latter part of this decade. Nevertheless, planners are already thinking in terms of 2010 and beyond and that implies a start on a definite programme by 2000. In the meantime there are several years in which to reflect on the best way forward.

It is against this background that ESA's FESTIP (Future European Space Transportation Investigations Programme) is set as a specific study and technological exploration and validation programme, complementing national activities.

National Efforts

In 1983, HOTOL, a launcher programme proposed in the United Kingdom, looked to have caught the imagination. It did not enjoy long-term national support, and its funding level is modest. Joint design studies with the Antonov Design Office are underway, concentrating on winged reusable rockets or spaceplanes launched from the Antonov An225 aircraft.

The German hypersonic technology research programme has been centred around Sänger, a fully reusable two stage to orbit configuration. The first stage is winged with turbo and ramjet propulsion, the second has rocket propulsion. Present work concentrates on the first stage.

The French programme of studies on advanced hypersonic propulsion (Programme d'études sur la propulsion hypersonique avancée, PREPHA) looks into supersonic combustion propulsion systems.

Emphasis on Reusability

Two ESA research programmes have a funding of some 3.2 million ECUs a year between them to place studies in industry for work on future launchers of a basic nature. In particular the funds are used to investigate:

- reusable rocket launchers using near-term technology
- subsonic and supersonic combustion air-breathing launchers
- advanced reusable rocket launchers and the associated flying test vehicles.

One requirement for any future launcher is that it should reduce the current or foreseen launch costs, implying greater payloads for equal or preferably lower costs. Studies that sought to use the basic Ariane 5 concept, but with reusable boosters, failed to match this requirement, and the near-term technology reusable rocket launcher concept has been abandoned in favour of a radical departure from the Ariane 5 base.

Winged launchers are another possibility, and studies are in hand to determine the feasibility of an SSTO (single stage to orbit) vehicle and to consider whether a two stage to orbit (TSTO) vehicle has operational and technical advantages. Underlying these studies is a fundamental need to identify what technologies are essential if such vehicles are going to be feasible.

It is interesting to summarise the mission requirements that are referred to in such studies: circular orbit at 450 km altitude, 28.5 degrees inclination, a launch from Kourou (French Guiana) or Istres (South of France), and a payload of 7 tons.

SSTO or TSTO

Indications are that the SSTO vehicle does not meet the demands, and work is concentrating on the TSTO concept.

If a true SSTO winged launcher is to be developed it could well depend on a "combined engine" propulsion system that comprises an air ejector rocket engine, a subsonic combustion ramjet, followed by a supersonic combustion ramjet (scramjet), and a final rocket engine. A study of such a concept has started.

From past experience ESA is aware that the national programmes are likely to develop to a point at which they could be offered as the basis for a European project. ESA has financial and legal means to accommodate such proposals but, again drawing on the past, knows that work has to be done to set up the necessary database and to achieve an interest from sufficient Member States to fund a major optional programme. Such preparations will form part of the FESTIP programme.

Over the coming years FESTIP is expected to concentrate on a number of reference concepts:

- the TSTO reusable rocket: a possible near term solution beyond Ariane 5, of known feasibility but unknown economy;
- the TSTO reusable air-breathing/rocket, such as Sänger; a possible solution in the long term of known feasibility but unknown economy;
- the reusable SSTO combined engine aerospaceplane, such as the NASP; a potential solution in the long term of unknown feasibility and unknown economy;
- the reusable SSTO rocket, such as Delta Clipper/Beta 2; a potential solution in the medium term of unknown feasibility and unknown economy.

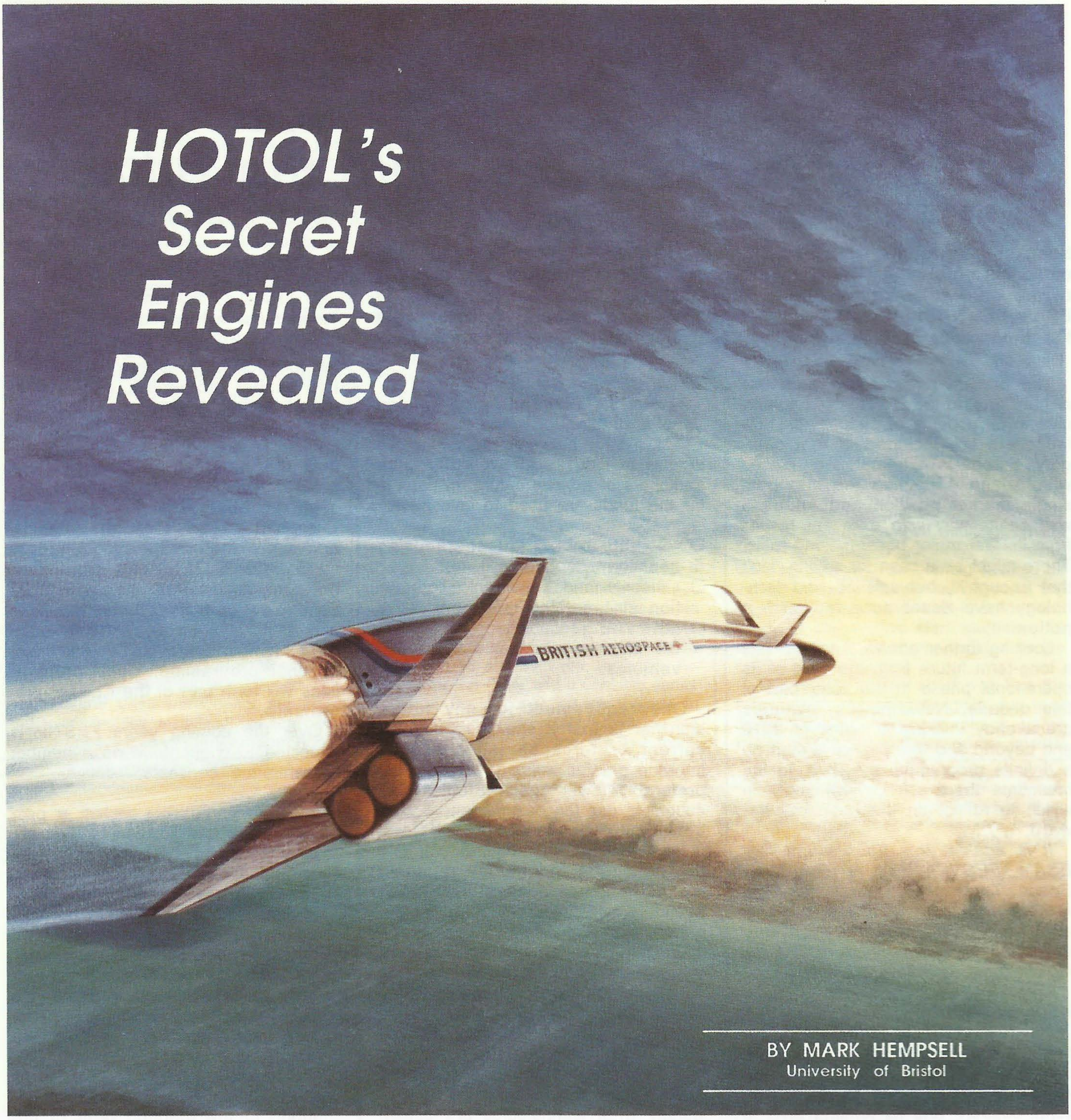
When looking so far ahead, technology studies are essential in fundamental disciplines such as aerothermodynamics, materials and structures, propulsion systems, as well as allied subsystem design.

It is ESA's belief that by 1995-96 it will have a clearer idea of what future space transportation systems Europe can expect to be within its technical and financial competence.

Acknowledgement

The assistance of Heinrich Pfeffer in providing material for this article is greatly appreciated.

HOTOL's Secret Engines Revealed



BY MARK HEMPSELL
University of Bristol

Artist's View of HOTOL in airbreathing mode. Showing main RB545 rocket engines, the hydrogen dump and the spill ramjet glow. *BAe*

Finally the secret of how HOTOL's RB545 airbreathing engine works can be revealed. Thanks to a change in Government policy, which now prohibits keeping patents secret without justification, the details of the engines used on HOTOL are now in the public domain. *Spaceflight* has asked Alan Bond, Managing Director of Reaction Engines Ltd., who was the engine's inventor, and Bob Parkinson, who managed the HOTOL project for British Aerospace (Space Systems), to explain precisely how it works.

Alan invented the engine in response to continuing discussions at the annual Space Transportation Symposia held by the BIS In the 1970's and into the mid 1980's. Several contributors to these meetings were trying to find ways to get a genuine reusable launch vehicle. These papers generally concluded, while there were clearly difficulties, that the time was ripe (even overdue) for a move away from conventional expendable launch systems.

At the 1982 symposium the French space agency, CNES, gave a presentation that outlined the Hermes/Ariane 5 route forward for Europe. The conservative timidness and lack of vision In this route Incensed Alan (and Indeed many others in the UK). As Alan pointed out; we were "seeing Europe embarking on new developments with 1960's technology." The French proposals seemed to rehash the Titan III/ Dynasoar concept which the Americans had abandoned in the 1960s as an Impractical route to manned space flight.

These regressive proposals must have seemed even more outrageous to Alan because at the time he was working with Tony Martin at the Atomic Energy Authority at Culham who was

engaged in research highlighting the importance of space capability in overcoming the Malthusian limits to economic growth. The CNES / ESA plan clearly did not begin to address this challenge. Alan said that Tony Martin's work was "in part" the motivation behind his efforts, although "my full motives were very complex."

So during 1982 Alan re-examined the problem of advanced launchers. Most of the vehicles proposed in the earlier symposia had centred on pure rocket systems, but these were always either marginal in performance, or needed two stages (with double the development costs). There was a widespread belief that a practical air-breathing system would solve the problem of achieving economic Single Stage to Orbit (SSTO), but all the candidate engine cycles had problems. Three main classes of system being considered were:

- Turbo-ramjets
- Liquid Air Cycle Engines (LACE)
- Scramjets

A turbo-ramjet combines a conventional turbojet with a ramjet. As the speed increases the turbojet progressively spills air into a ramjet which enables a speed of about Mach 5 to be reached. Above this speed a separate rocket engine would be required to take the vehicle up to Mach 27 (orbital speed). The main problem is that turbo-ramjet engines are heavy and this dead weight must be carried into orbit.

As Bob Parkinson explains; "turbojets, have (in rocket terms) very high specific impulses, but poor thrust-to-weight ratios; about eight for the best military engines and that is "naked". Wrapping a supersonic intake around the engine might well double the weight. On an SSTO, after Mach 5 the engine would be "dead weight" to be carried into orbit. Several companies have looked at turbo-ramjets and none has managed to increase the thrust-to-weight ratio to a level where they would be attractive as "first stage" engines for SSTO"

The second class of engines is that of pre-cooled engines. In the past these have been typified by LACE (liquid air cycle) concepts. Here, in the initial stages of flight, air is liquefied using liquid hydrogen from the propellant tank and then pumped into a rocket chamber, which later can be used as a pure rocket. This engine generates higher thrusts for a given weight than a turbo-ramjet because the air is burnt in a rocket engine. However to liquefy the air much more hydrogen must be used than is needed to burn with it. These inefficiencies mean LACE powered vehicles still do not look convincing as launch systems.

The final candidate engine class is the scramjets. The name comes from "supersonic combustion ramjets". In these devices the air is never slowed down to subsonic speeds during its passage through the engine. Fuel injection, burning and expansion all take place at supersonic speeds and unlike all the other engine concepts the scramjet can realistically exceed Mach 6. This made engineers believe scramjet vehicles could be made to reach orbit and therefore be the best candidate for SSTO. This is why they are the experimental engines on the American X-30 NASP test plane.

However the problem with scramjets is that another engine is needed (either a rocket or turbo-ramjet) to get up to the hypersonic airspeeds where the scramjet starts working. The vehicle will also need a rocket to finally carry it into orbit after the airbreathing phase. This leads to combinations such as rocket/ramjet/scramjet/ rocket or turbo-ramjet/scramjet/ rocket combinations. John Scott Scott, the Rolls Royce RB545 project leader, referred to such vehicles as "the Smithsonian in orbit - one example of everything."

All these extra engines mean either extra engine weight, or extra fuel, or both and this greatly effects the overall vehicle performance. When this is accounted for getting into orbit depends upon the top speed a scramjet can achieve. The original goal of the NASP programme was to reach Mach 25 (very close to orbital speed) while air breathing, but in reality many engineers believe Mach 16 may be the practical limit. This would make scramjets less attractive for launch systems.

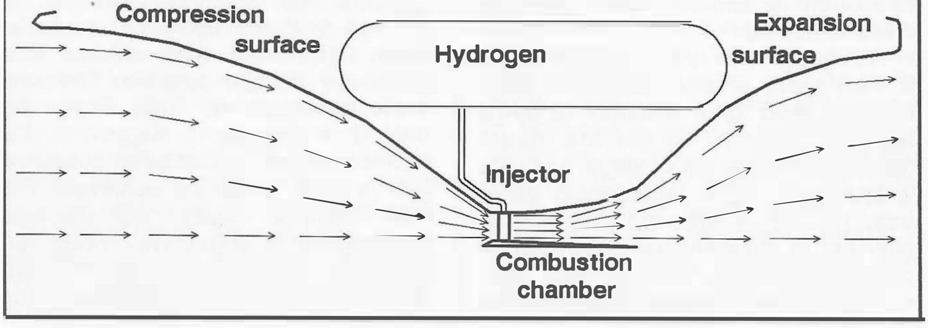
Although apparently very simple devices, a shaped surface and an injector/igniter system, in practice scramjets are the most complex of engines. There is no fixed surface that will act as scramjet at all speeds, so the engine must constantly change its shape inside as it speeds up. As Bob Parkinson explains. "You can design a simple scramjet for one speed but the geometry changes as the speed changes. Scramjets therefore become a variable geometry device. This means that there is a range of operation. If you increase the top Mach number then you must increase the bottom Mach number also. In the HOTOL work on scramjets we found an optimum transition point for the switch to rocket propulsion in the Mach 13 - 15 range; not because they do not work above that point, but because a scramjet designed for such speeds would be ineffective at lower Mach numbers"

Another problem is the injection of the hydrogen into the hypersonic airstream. This becomes complicated especially as there is only a few thousandth of a second in which to mix, burn and expand the exhaust before the airstream has left the engine. The main problem is the mixing of the hydrogen fuel with the air. Bob explained, "scramjets have an inherent contradiction - they demand good and rapid mixing between the air and the hydrogen, but without disturbing the supersonic airflow at all!". At hypersonic speeds maximising the time for this process to happen requires that the whole length of the body of the vehicle becomes part of the engine.

Another reason for the whole vehicle body becoming part of the engine is the size of intake. As the air speed increases so the area of the intake must also increase. (See panel overleaf for explanation). At very high speeds one requires very large intakes - in fact as big as the whole aircraft. An additional problem is that once and intake is designed for high speed, at lower speeds it will scoop up too much air. We will meet this problem again when we look at HOTOL's intake.

To resolve the debate about the scramjet's real potential requires research. Here another problem arises. To research scramjets hypersonic airflows are need at the intake. One must either rely on computer simulations, very advanced wind tunnels or flight experiments on rockets. All these expensive research tools have been used during scramjet development work. However even then the results can be inconclusive. The detailed analysis of the mixing process is the problem, as Bob explained. "There is no confidence that computer modelling is up to the job, wind tunnels certainly aren't. Therefore you need a test vehicle (like the X-30 NASP) be-

Schematic of a scramjet.



fore you know whether your predictions of performance are right at all."

While at first sight scramjets do look as if they may offer a route to SSTO, with closer examination this is far from certain. The cost, technical risk, and complication involved in the development of a workable scramjet vehicle mean it does not look a promising route for low cost transport to orbit. Bob summed up the view of the HOTOL team, "scramjets do not have an intrinsic performance benefit and even if they did the cost of engineering the hardware required would be much greater than the other options. The demise of the X-30 NASP may be a belated realisation of this fact."

Alan summed up his view on the scramjet's potential as follows; It "may provide economical high Mach number cruise propulsion, but it is not suited to an accelerator (the same is true of ramjets). In addition it is very expensive to develop compared with a precooled hybrid engine."

Alan's New Look

With these problems in mind Alan Bond reexamined the precooling concepts like LACE. He did much of the detailed mathematical modelling required to explore the different engine cycles on a now famous Sinclair Spectrum hooked into the television in his lounge. Alan explained the importance of the computer in his work, "The spectrum computer (which I still use once in a while) is more powerful than the computer we used on the RZ20 LOX/LH engine we built in 1968. It cost £400 and the UK space programme never had better value for money! The personal computer has changed science and technology. Today individuals at home can cover in a few weeks tasks which once took teams months to complete."

As a result of this work Alan proposed a new engine cycle with three important alterations to the basic LACE theme, which had never been put together in any previous proposals.

The first alteration (and most important) was a recognition that the air does not have to be liquefied. Air as gas can be fed to a rocket engine and it will still work. This means the energy absorbed by the air while liquefying (the latent heat of vaporisation) is saved and less liquid hydrogen is need to cool the air and the engine becomes more efficient.

This suggestion is not as obvious as it may seem at first. Launch system engines need large amounts of thrust to "fight" gravity. To get this thrust requires the burning of large amounts of propellant. If the propellant is gaseous, feeding it into the combustion chamber in sufficient quantities can be difficult. Getting the air to a high enough density while still a gas is not a trivial problem.

Bob emphasised the importance of this feature. "The amount of work you do compressing the air depends on the (absolute) starting temperature. To get a high thrust-to-weight ratio you need high pressure in the combustion chamber (150 bar in a rocket engine compared with 8-10 bar in a jet engine). By cooling to just above the liquefaction point of air, the compression energy was much reduced. Big diesel lorries sometimes have the magic word "intercooler" on their front. That does a similar thing, cooling hot air that has been compressed in order to compress it some more and increase the amount of air being fed to the engine."

The second alteration was to suggest that heat exchangers (to cool the air and heat the hydrogen) could be made lighter and more efficient than previously thought possible. The concepts developed by Rolls Royce not only vindicated Alan's suggestion, but showed he had in fact been conservative in what could be achieved. The main technical concern with the heat exchangers is surprising. "Frost formation is the main difficulty with this type of engine," Alan explained. "The main objective of the Rolls Royce test programme was to show that frost formation could be successfully countered".

The third alteration was to dump the hydrogen used to cool the air. Any air cooling engine will produce surplus hydrogen as a result of the cooling cycle, and many previous engine cycles tried to find ways of burning this fuel, which always ended up adding to the inefficiencies of the engine. Alan realised with the current state of our technology and understanding the most effective approach was to accept the basic inefficiency of dumping fuel overboard unburnt.

Did Alan feel there was a single key to his success in find a way to produce a workable hybrid engine, where so many previous efforts had failed? "Any hybrid engine must end up being a very efficient rocket for most of the flight," Alan replied. "I began with a good rocket engine and made it a bad air-breather. Everybody previously had done the reverse."

The Engine Cycle

The figure shows a simplified flow diagram for the RB545. In practice some of the switching and flow paths are more complex than shown, but all the principal features of the engine cycle are illustrated. The engine operates in two modes (airbreathing and pure rocket) and it is easiest to consider each separately. Starting with the airbreathing mode.

To understand the airbreathing cycle it is easiest to first follow the air flow path, and then look at the hydrogen flow path. The engine starts by sucking air through the air intake at a rate of 230 kg/sec. In the process the air is compressed to about two atmospheres and rises in temperature. The air temperature varies with the speed, but in the worst case at Mach 5 it is 1250K. When the air reaches the front of the heat exchangers the temperature is too high and the pressure too low for it to be fed to the engine.

To reduce the temperature the air is fed through two heat exchangers (called 1 and 2). These heat exchangers cool the air until it is just above its condensation point by heating hydrogen from the fuel tanks. The work needed to cool the air depends on its temperature and we have seen this varies enormously with the air speed. At Mach 5 something like 300 Megawatts of heat is transferred. But whatever the temperature of the air when it enters, after the heat exhangers it is at the same temperature and pressure ready for the next stage of the cycle.

After the heat exchangers the now very cold air is compressed to around 150 atmospheres by the compressor turbines so that it can be fed into the rocket chamber. It is the compressor that provides the sucking action to

Intake Area

The amount of air swallowed by the intake (the mass flow) is given by:

$$\text{Mass/sec} = \text{Air density} \times \text{Air speed} \times \text{Intake Area}$$

The air mass flow determines the amount of fuel that can be burnt and hence the thrust produced and this cannot be made to vary very much. Hence the mass flow must remain roughly constant during the air breathing phase. Given the intake area is fixed as air speed increases so the vehicle must climb to higher altitude to reduce the air density. In the case of a launch system this is what we want to do in any case to reach orbit.

However the engine must also consider the dynamic air pressure (called "q" by aerodynamicists), which is the pressure due to the air hitting the front of the vehicle as it moves. The dynamic pressure (q) of the air at the intake is given by:

$$q = \tfrac{1}{2}\ \text{Air density} \times (\text{Air speed})^2$$

This determines the loading on the airframe and within the engine and, like the mass flow, it must also remain constant. By combining these two equations to give an expression for intake area we get:

$$\text{Intake area} = \frac{\text{mass/sec} \times \text{Air speed}}{2q}$$

If mass flow and q must be kept roughly constant, it follows that as the air speed increases so the area of the intake must also increase.

draw the air through the intake and in this respect it is identical to the front-end of a conventional gas turbine engine and explains why the RB545 can work from a standing start in still air.

Because the engine can operate in still air it greatly simplifies testing. A key problem with scramjet and ramjet development is they can only be tested in high speed airflows. However the HOTOL engine can be developed and tested in a more conventional manner on "fresh air" facilities. Alan reinforces this advantage. "My main concern was test facilities. All successful prime movers which have been developed use simple facilities."

In raising the pressure the air temperature rises again and it is quite hot (around 750K). However it is still cool enough to be used as a coolant for the rocket motor combustion chamber before being squirted into the chamber to be burnt with the hydrogen. Note also that a small amount of air is bleed off to be fed to a "pre-burner" which will be discussed later in the hydrogen flow.

Now consider the hydrogen flow. This is drawn from the fuel tanks by a two stage centrifugal compressor and fed directly to Heat Exchangers 1 and 2 to cool the incoming air. The flow rate is about 23 kg/sec and the pressure about 250 bar. As we have seen the amount of work need to cool the air depends on the air speed and can vary enormously. So the temperature of the hydrogen leaving Heat Exchanger 2 must also vary. To bring the hydrogen up to constant conditions of 950 K and 200 bar pressure a third heat exchanger (appropriately called Heat Exchanger 3) is used. This heat exchanger draws its heat from hydrogen later in the flow cycle which has been heated by the pre-burner.

After leaving Heat Exchanger 3 the hydrogen is used to drive the hydrogen feed pump and then the flow splits. Two thirds of the hydrogen is fed to the turbines that drive the air compressor. After leaving the turbines this hydrogen is dumped over board through a vent. As we have already seen this proposal to simply dump fuel during the air breathing phase is one of the novel features that Alan incorporated into the design.

The other third of the hydrogen is fed to the pre-burner where a small amount of air is mixed and burnt to increase its energy content so it can feed heat into Heat Exchanger 3. After leaving Heat Exchanger 3 the hydrogen is injected straight into the rocket combustion chamber where it is burnt with the air.

During airbreathing the combustion chamber runs at a temperature of about 2700 K and about 100 bar pressure. It is then exhausted through a 100:1 expansion ratio nozzle. Because only a third of the hydrogen flow reaches the chamber, and because the air contains two thirds inert nitrogen, the thrust in airbreathing mode is about half the pure rocket at about 340 kN.

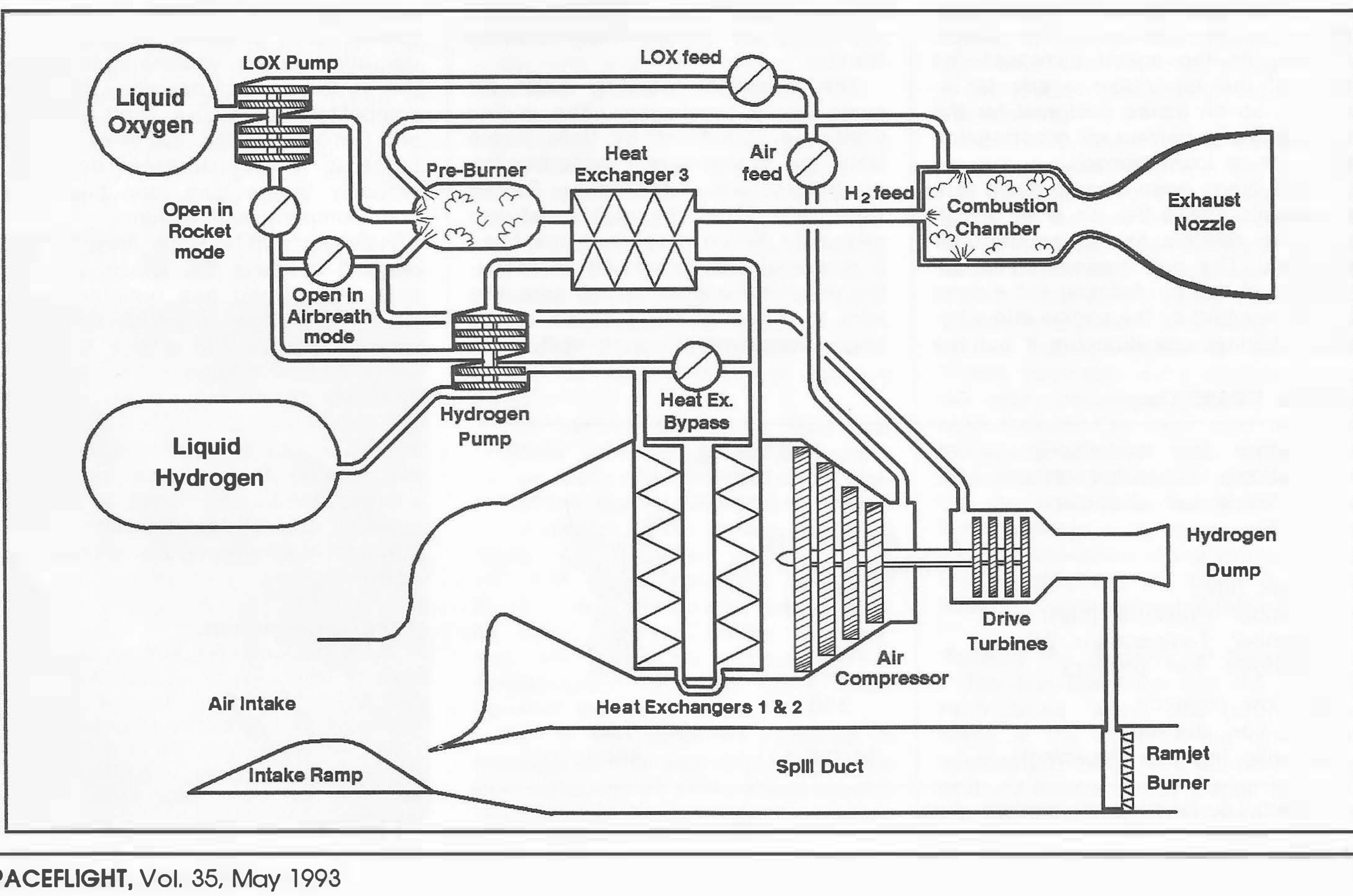
The Rocket Cycle

The transition to a pure rocket engine occurs between Mach 5 and 6. The key factor determining effective performance in the airbreathing phase is "momentum drag". All the air scooped up by the intake must be slowed down from the vehicle's air speed to almost no velocity. This enormous loss of momentum must be accounted for when considering the momentum added by the rocket chamber thrust. So the effective performance of the engine deceases as the speed increases until much above Mach 6 the energy stored in the fuel is needed just to compensate for the energy lost by the air in being slowed down. The engine's performance in terms of specific impulse (the impulse the rocket provides per kilogram of propellant) drops below a pure rocket engine.

Another factor on deciding the transition to rocket mode is the temperature within the air intake which we have seen reaches 1250 K at Mach 5. While the outside of HOTOL has the re-entry thermal protection which can withstand higher temperatures than this, the inside of the engine is a more sensitive region, and material limits are being reached in the Mach 5 to 6 region.

Converting to rocket mode obviously involves switching out the air collecting and compressing components. The hydrogen feed to the drive turbines is cut off - stopping the hydrogen dumping - and Heat Exchangers 1

Simplified flow diagram of the HOTOL RB545 engine.



and 2 are bypassed. This means that the hydrogen fed to Heat Exchanger 3 is now straight from the tank and Heat Exchanger 3 needs to pump all the energy into the hydrogen that previously was coming from the air - around 300 Megawatts.

As in the airbreathing mode the hydrogen leaving Heat Exchanger 3 is used to drive the hydrogen pump. But after this the flow is no longer split rather it is all fed to power the liquid oxygen feed pump. It then reaches the pre-burner where some oxygen is burnt to increase the energy content of the hydrogen flow before entering the heat supply side of Heat Exchanger 3 and then on into the combustion chamber as before.

The oxidiser in the rocket mode is liquid oxygen (LOX). We have already met the feed pump as it is powered by the hydrogen flow. This pumps LOX at 400 bar to the cooling jacket of the combustion chamber and then into the combustion chamber itself. There is also a bleed off to supply the pre-burner.

The pure LOX, hydrogen propellants improve the performance of the engine. The combustion chamber temperature rises to 3400 K and the pressure to 150 bar. This produces a thrust of 735 kN. and a specific impulse of 4500 Nsec/kg.

The Spill Ramjet

As the HOTOL study work continued and the air intake designed in detail, a spill system was found to improve performance. A spill system is a method of handling a problem already discussed in relation to high speed intakes. As the speed increases the area of the air intake needs to increase, so an intake designed for the top speed of a vehicle will scoop up too much air at lower speeds.

Once it has been slowed down in a supersonic intake the air is at a high pressure relative to the ambient air pressure. The spill system takes advantage of this by directing the excess air not required by the engine into a by-pass channel and dumping it out the back. There is a nozzle within the duct to accelerate the air, convert the air pressure back to air speed and recover as much of the momentum as possible.

In HOTOL a burner was added to the by-pass channel to convert the spill duct into a simple ramjet. The fuel for this "Spill Ramjet" was some (but not all) of the hydrogen being dumped by the drive turbines. As Bob Parkinson explains it was never intended to be a high performance system.

"With HOTOL it was decided to swallow all the incoming air into the intake, slow it down to subsonic speeds, and then scoop out just as much as was needed by the engines. The rest can be expanded out the back, and essentially the air regains its momentum in the expansion process. There are losses in the process, but by burning the spill hydrogen you can overcome these losses. The idea was that the spill ramjet did not have to be very effective, and was not something requiring extensive ground test development facilities. Instead we hoped that it would get "tuned" during flight development, and generally give us a bit of extra performance and hence margin."

The spill-ramjet would be used between Mach 0.5 and Mach 4.5, where the speed and quantity of air in the by-pass channel is adequate to sustain a ramjet action. At the peak airflow in the transonic region around a tonne of air a second is passing through the spill duct. The artist impression of HOTOL in airbreathing mode clearly shows both the four main rocket chambers, and the glow of the spill-ramjet in the exit of the two by-pass channels below them.

The industrial teaming made for some quaint terminology. The engine work was undertaken by Rolls Royce while the aerodynamics (including the air intake) was handled by British Aerospace. When the spill ramjet was added by British Aerospace the force it produced was described as "negative drag" rather than "thrust" as a little joke to preserve the niceties of the engine/aerodynamic work spilt.

Table: RB545 Data

Mass (less intake/spill) :	2,500 kg	
Nozzle expansion ratio:	100:1	
Nozzle exit diameter:	1.82 m	
	Airbreathing (Mach 5 at 26 km)	Rocket (Vacuum)
Thrust (kN):	340 *	735
Chamber Pressure (bar):	100	150
Chamber Temperature (K):	2700	3400
Hydrogen flow (kg/sec):	23	23.3
Air flow (kg/sec):	240	-
LOX flow (kg/sec):	-	140
Specific Impulse (Nsec/kg):	14,780 *	4500

* Nett, i.e. ignoring momentum drag.

The Future

The history of the RB545 reflects the best and the worst of Britain. It is a source of pride in the UK astronautical community that the solution to the almost legendary problem of a practical airbreathing engine was found by a British engineer. It is not only a tribute to an individual talent, but also testifies to the overall culture of UK space engineering in which he operates.

However from the point of view of advancing mankind into space it must be frankly acknowledged that the UK was the worst possible country for this breakthrough to occur in. The Government, with its uniquely hostile policy on space infrastructure, did nothing to support the exploitation of the potential of the invention.

So what does the future hold for the RB545?

The data presented in the article represent the engine status as in 1989. By that time Rolls Royce decided that the investment required to take the engine through its development phase and produce an operational engine in terms of company manpower, money and political capital was too large given the eventual market in terms of the number of engines required by the HOTOL project (even on the most optimistic assumptions), and has not supported any further work on the RB545.

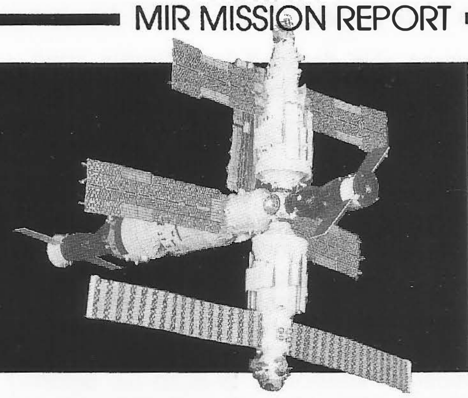
It is difficult to fault Rolls Royce's decision. It is a commercial company operating in a very tough marketplace and it must husband its investments wisely for the benefit of its employees and shareholders. However one must question why a British firm should be operating in an environment where this is the correct decision? Its main competitors in the USA, Pratt & Witney and General Electric, are likely to have come to a very different decision, probably to the long term benefit of both company and nation.

However, while Rolls Royce have decided to leave the space launcher field, Alan Bond has remained very active and has founded Reaction Engines Limited with a view to developing a new engine called SABRE. This new engine incorporates many of the features of the RB545 cycle, but has used the experience gained on that engine to introduce significant improvements. The result is a more complex and slightly heavier engine, but also one with better airbreathing performance.

Acknowledgements

The author would like to thank Bob Parkinson of British Aerospace, and Alan Bond and Richard Varvill of Reaction Engines Limited for their assistance in preparing this article. He would also like to thank Rolls Royce plc for permission to publish the performance and other data related to the RB545.

MIR MISSION REPORT



First Docking of Three Craft at a Space Station
New Crew Takes Over

On January 10 the press were introduced to the crews to go to the Mir station on January 24 in Soyuz TM-16 and take over from Solovyov and Avdeyev. The prime crew consisted of Gennadi Manakov who made a flight to Mir between August and December 1990 and Aleksandr Poleshchuk, an engineer from the Energiya NPO firm who would be making his first flight. The reserve crew consisted of Valsili Tsibliyev and Yuri Usachev who were both rookies.

BY NEVILLE KIDGER
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Launch was planned for January 24 with a docking at the Mir station scheduled for two days after the launch. The return to Earth of the current crew was scheduled for February 1. A major goal of the new mission was the testing of the docking system to be used for the link-up of the Buran shuttle orbiter with the Kristall module. Such a mission is now very doubtful but the docking system developed for the mission is also to be used for the docking of the American Shuttle orbiter in 1995. The androgynous docking system is similar to that developed in the mid-1970s for the Soviet/US link-up during the Soyuz-Apollo mission. The new version, first shown in Paris in 1989 is called APAS-89. For the first time in the history of the Soviet/CIS programme a manned craft would dock at a 90 degree angle to the axis of the space station. The port to be used was on the front of the Kristall module and the docking manoeuvre was to be conducted manually by the cosmonauts.

In a further evaluation of the dire economic state being encountered by the CIS space programme, the head of the Gagarin Space Training Centre, Colonel Petr Klimuk said that consideration had been given to send both crews to the launch site on the same aeroplane rather than on separate flights which had been the practice previously. However, in keeping with past practice, both crews arrived at Tyuratam in separate planes on January 11.

By January 15 the cosmonauts onboard Mir had completed pumping fuel and oxidiser out of the tanks of the Progress M-15 cargo ship into Mir's tanks. Scheduled repair and maintenance activities in the station were conducted in preparation for the arrival of the next crew. On January 23 it was announced that the Soyuz TM-16 crew would be launched at 0558 GMT the following day with Manakov and Poleshchuk confirmed as the prime crew.

Kristall module: Docking port for reusable spacecraft such as Buran and the US Space Shuttle. It was first used by TM-16 in January 1993. *Karl Heinz Rohrwild*

Soyuz TM-16's Flight to Mir

On schedule, at 0558 GMT on January 24 the carrier rocket with Soyuz TM-16 was successfully launched into grey skies from a snow-covered Kazakh launch pad. As normal for a Soyuz TM ferry mission, Manakov and Poleshchuk spent the first day correcting their orbit and checking the spacecraft systems. The first orbital corrections left the spacecraft with a height of 308 x 257 km and a period of 89.9 minutes. On the second day, Soyuz TM-16 approached the Mir complex and docked. A radio commentary of the event was provided by Vasili Tsibilyev, the reserve for Manakov. He described how TM-16's automated approach device had brought the craft to within 150 metres of the Mir complex, from which point the cosmonauts assumed manual control and approached to some 70 metres of the Kristall module's forward docking port. After various checks had been made of the Soyuz's engine control system and TV pictures had been returned showing the line-up of the two craft, the go-ahead was given for Manakov to approach and dock with the Kristall module.

Tsibliyev said that, although there was "absolutely nothing conventional" about the docking, it had proceeded without a hitch. The link-up was timed at 0741 GMT on January 26. For the first time three craft - Soyuz TM-15, Soyuz TM-16 and Progress M-15 - were docked to an orbital station. Manakov and Poleshchuk moved into the Mir complex to be greeted by Solovyov and Avdeyev about one orbit after the docking.

Speaking to the press after the successful docking, officials of the Flight Control Centre (TsUP) revealed that Manakov and Poleshchuk would be the first crew to try and unfurl a solar sail in space in early February in an experiment using the Progress M-15

cargo ship deferred from late in 1992 and would also conduct 3 EVAs starting on April 16.

After settling down into their new home, the cosmonauts began conducting the first of their many joint experiments. On January 27 all four cosmonauts were involved in an experiment to expose various construction materials to open space through the airlock of the base block. The samples were then checked using the Elektrotopograf equipment to scan for deformations. On January 28 they conducted another Resonance experiment on the space complex's dynamics, such tests having been performed since the first three-craft docking with Soyuz 26/Salyut 6/Soyuz 27. After the docking of Soyuz TM-16, Mir comprised of new fewer than seven different craft.

Soyuz TM-15 Returns to Earth

The following day Solovyov and Avdeyev began their final preparations for the return to Earth by undergoing checks of their cardiovascular systems using the Chibis leggings. Late on January 31 (early on February 1, Moscow Time) the crews parted and Solovyov and Avdeyev crossed into Soyuz TM-15. The hatches between ship and station were closed at 2120 GMT and at 0000 GMT the craft was commanded to undock from the complex.

The Soyuz engine was ignited above Africa for a 255.6 second burn. The velocity of the craft decreased as it entered the Earth's atmosphere and it deployed its parachute at lower altitude, landing at 0352 GMT.

On February 5 the two cosmonauts were awarded honours by President

Last Months of 1992: Solovyov and Avdeyev Continue Experiments on Mir

September 1992

On September 18 the two cosmonauts aboard the Mir orbiting complex, Anatoli Solovyov and Sergei Avdeyev, completed four exhausting forays into open space to mount a control block on the 14-metre high Sofora girder. The two cosmonauts were very busy that day having also conducted further experiments with the Mariya magnetic spectrometer which is aimed at determining possible interrelations between the intensity of streams of high energy elementary charged particles in space and seismic activity on Earth. Tests of the engine unit were also conducted along with their "regular" work. They were also using the Priroda-5 camera system mounted in the forward part of the Kristall technology module for Earth observation of water basins, forests and agricultural land.

By September 22 the Terra-K programme was underway for observing and photographing the Earth's surface under a commercial agreement. Photography and spectrometry of farmland in Krasnodar Kray and in southern Novosibirsk Oblast was on the programme.

On September 24 they began a smelt in the Krater-V installation which would last for 130 hours for growing monocrystals of a high temperature alloy based on the oxides of yttrium, barium and copper. By September 30 the smelt had been completed.

October 1992

On October 2, Earth observation covered the region of Chernobyl, Krasnodar Kray, the Crimea and the Volga. Measurements with the Mariya spectrometer continued and another series of tests (code-named Resonance) of the stability of the structure of the complex was conducted.

On October 6 more smelting work commenced using the Gallar unit to produce monocrystals with the properties of a high-temperature superconductor.

On October 12 the cosmonauts underwent medical tests and further photographs of the Earth's surface were taken centred around studies of the ecological state of agricultural areas, water basins and forests.

Astrophysical work was conducted on October 13 with the Buket and Granat spectrometers in addition to medical tests.

Loading of the Progress M-14 unmanned cargo resupply ship with used equipment occupied part of October 16 in preparation for its separation from the complex at 2030 MT on October 20. The undocking actually took place at 1946 MT on October 21.

Early the next morning Progress M-14 was commanded to fire its retro rockets and began its descent. The retrievable capsule mounted in the docking unit position was ejected and descended to Earth, landing by parachute at 0309 MT in the designated area of the CIS. The Progress craft itself burned up in the atmosphere.

At 2020 MT on October 27 the Progress M-15 cargo ship was launched into an initial orbit of 233 x 194 km, period 88.5 minutes, inclination 51.6 degrees. The craft docked with the Kvant port of the Mir complex at 2206 MT on October 29 delivering expendable materials and new scientific equipment for the cosmonauts to use.

November 1992

On November 3 the cosmonauts began using the Roentgen X-ray telescopes on Kvant to study an X-ray pulsar in the Vela constellation discovered two years earlier by the Russian/French satellite Granat. The object is thought to be a binary star system.

For the first time during the mission the Russians said that the Inkubator-2 device was being used to study the embryonic development of Japanese quail eggs which would be observed until they hatched. Solovyov first monitored the use of the Incubator during his extended flight in 1990 but the chicks that hatched had died soon afterwards, although the cosmonauts were able to show the chicks floating around in the microgravity conditions of the complex. This time, the experiment was completed after two weeks on November 17. ITAR-TASS said the men had observed the changes undergone by the embryos but did not state whether the eggs had hatched. Later Avdeyev confirmed that the chicks had hatched but gave no word as to their fate. The results were to be returned home for study.

November 17 also saw the start of the Kondor experiment with the aim of controlling the radiation levels inside the complex. The experiment was a commercial one held under an agreement between the NPO Energiya and the Canadian space agency. The cosmonauts were to "video detectors intended to control radiation conditions taking the neutron space radiation constituent into account".

At noon MT on November 20 the cosmonauts ejected the MAK-2 satellite from the base block's airlock. The small satellite was designed to study physical processes occurring in the Earth's ionosphere. The first Mak satellite, with a mass of 16.5 kg, was ejected on June 17 1991 from the Mir station but it failed to deploy its antennae and was presumed to have suffered a power failure. The flight programme was supposed to last for three days.

On November 23 the men began yet more work with the X-ray telescopes of Kvant and conducted the Migmas experiment, devised for the flight of the Austrian cosmonaut Franz Viehbock in October 1991.

December 1992

On December 1 it was announced that a further series of readings had been obtained from the Danko experiment mounted outside Kvant-2 to study the effects of prolonged exposure to space on various materials. Another Resonance experiment to determine the dynamic characteristics of the huge complex was also carried out.

On December 3 the cosmonauts began a smelt in the Gallar unit intended to last 140 hours and grow a monocrystal of zinc oxide, a semiconductor with improved structural and electrophysical characteristics. The work was completed on December 11 and on December 20 a 130-hour-long smelt was started to grow a zinc oxide monocrystal which was completed on December 26.

During December 4-8 a video was taken of a tropical cyclone in the Indian Ocean at the request of meteorologists and on December 8 new batteries delivered to Mir by Progress M-15 were installed.

On December 18 the cosmonauts used the Glazar 2 telescope and continued work with the Alice instrument, made by the French, to study thermal transmissions in microgravity. On December 29 the Glazar-2 telescope was focused on the constellation Perseus.

On December 22 another Resonance test was made along with continuing astronomical observations.

By December 25 the cosmonauts were using the EFO-1 photometer to study the Earth's atmosphere and turned the telescopes of Kvant to a source in the Virgo constellation. Over the following days more astrophysical observations were conducted on the object in Virgo and with the Glazar-2 telescope in uv light.

The New Year Begins

January 1 1993 was a day of rest with the cosmonauts' families coming to the Flight Control Centre to speak with them. It was also Avdeyev's 37th birthday. For the second time since the collapse of the Soviet Union a cosmonaut crew celebrated the Orthodox Christmas of January 7 in orbit.

Inside the Kvant 2 module looking towards the EVA hatch. *Karl Heinz Rohrwild*

Boris Yeltsin, Solovyov receiving the Order of the Friendship of Peoples whilst Avdeyev was made a Hero of the Russian Federation and awarded a Gold Star Medal. Solovyov was already a Hero of the Soviet Union following his first mission in 1988.

Spectacular Start for New Crew

On February 4 Manakov and Poleshchuk helped complete an extraordinary and spectacular experiment which had been planned initially for the end of October 1992 but repeatedly postponed.

The experiment was aimed at testing the deployment from the Progress M-15 craft of a 20 metre diameter, 5 micron thin, solar sail constructed from aluminium coated Kevlar. If successful, the sail, with its mirror-like surface, would reflect sunlight and be seen on Earth. A much larger version (several kilometres in diameter) could, according to the experiment's proponents, reflect sunlight to light up the northern regions of Russia during the long winter months.

Progress M-15 separated from the complex at 0045 GMT on February 4 and moved away from the station to a distance of about 160 metres. It turned through 180 degrees so that its engine unit faced the complex, then the Znamya container mounted in place of the craft's docking unit began to spin (at the planned rate of 570 degrees per second) causing the solar mirror to slowly unfold by centrifugal force.

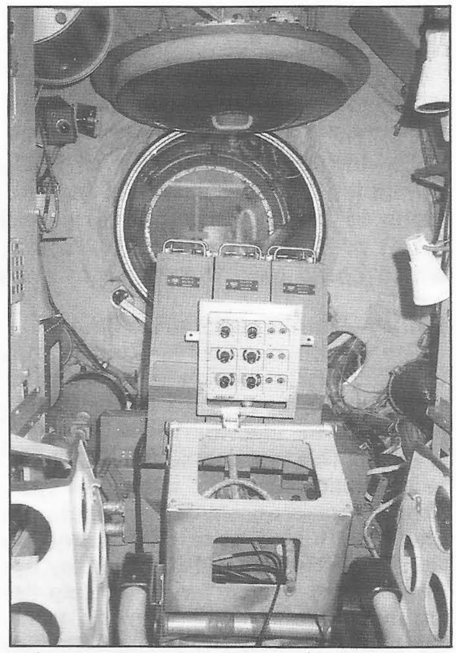
The mirror was designed in "petal" form so that it would open out in sections, one section taking longer than the others to unfurl. Then, at a distance of 230 metres from Mir, the spin rate was reduced to 84 degrees per second.

Spectacular TV pictures were later shown of the Progress craft, with the spinning mirror, floating past the windows of the station. The video pictures from Manakov and Poleshchuk were amongst the most spectacular of a craft in Earth. orbit yet returned. They showed the Progress against the bright blue and white of the Earth, and, as the distance between the craft and station grew, against a blue ocean. After some 6 minutes the mirror was jettisoned, to be destroyed In the Earth's atmosphere later. The separation was clearly shown on the cosmonauts' TV coverage.

During the brief experiment, according to press reports, the mirror could be seen from the Earth as a bright momentary flash from underneath its flight path which passed from France, through Germany to Belorus. However, viewers had to be within a 4 km wide swath underneath the craft to glimpse it.

Designed by specialists from the Space Regatta Consortium and the NPO Energiya, the equipment of the Znamya experiment (also known as "New Light") was just 40 kg in mass with the reflective mirror just one tenth of that weight. The experiment cost $60,000 according to one source.

However, the cosmonauts had not yet finished with the Progress craft itself. On February 5 the automated systems of the Progress craft were used to approach the complex until the distance was just 200 metres. From that distance the craft was then commanded from a control panel on the Mir station in a test of telerobotic control of spacecraft guidance. The experiment lasted for about 12 minutes and the craft was then commanded into an independent orbit from where, on February 7, it was de-orbited by remote control to burn up in the atmosphere.



Inside the Kvant 2 module looking towards the EVA hatch and airlock. The MKF-6MA camera is in the foreground *Karl Heinz Rohrwild*

The photographs in this article were taken in the Cosmonaut Training Centre (TsPK) at Star City.

Mir Programme for 1993

The Deputy General of the Russian Space Agency, Boris Ostroumov said on 11 December 1992 that three manned launches and six flights of the Progress M cargo ships were scheduled for 1993.

The first manned launch was on January 24 when a two-man replacement crew was sent to the Mir station. In July the next replacement crew will be accompanied by French cosmonaut Jean-Pierre Haignere and the mission will last for 3 weeks. At the end of 1993 a mission will start which will last for 1½ years and will include a doctor.

In a schedule released by the Flight Control Centre (TsUP) on 30 November 1992 the following dates for missions to and from Mir were announced.

Ship	Date	Crew
Launches		
Soyuz TM-16	24 January	Manakov/Poleshchuk
Progress M-16	3 February	Unmanned
Progress M-17	23 March	Unmanned
Progress M-18	18 May	Unmanned
Soyuz TM-17	1 July	Tsibilev...Haignere.. Usachev/Deshays
Progress M-19	27 July	Unmanned
Progress M-20	12 October	Unmanned
Soyuz TM-18	16 November	TBD
Landings		
Soyuz TM-15	30 January	Solovyov/Avdeyev
Soyuz TM-16	21 July	Manakov/Poleshchuk

During 1992 Ostroumov said that over 7000 pictures of the Earth had been taken from Mir with resolutions varying from 10 to 40 metres covering 35 million square kilometres. Areas included the CIS, Europe and America and were taken for the Priroda State Centre and the German firm Kayser-Threde. On the Kristallizator, Krater-B and Gallar installations the cosmonauts had smelted gallium arsenide, cadmium sulphide and zinc oxide to a weight of 600 g.

Fast-Track Back

General Dynamics Announces

Following hot on the heels of FLO, an independent study funded by the Space Systems Division of the General Dynamics Company, based in San Diego, California, has shown another approach by which early human missions to the Moon might be completed. GD engineers view their much more minimalistic Early Lunar Access (ELA) programme not as a direct competitor to NASA's FLO, but rather as an interim preparatory programme which could lead the way into the more ambitious FLO at a later date.

Shuttle Launch for Lunar Crews

The launch procedures used in the GD plan are a little more convoluted than the direct approach which NASA proposes to use for the FLO programme. This is because the ELA plan relies upon currently available systems, including NASA's fleet of Shuttles. The adoption of a heavy lift launch vehicle was a deliberate ploy by the Office of Exploration to insulate its proposed Moon-Mars missions from the heavy workload which the Shuttle faces in the Space Station era. However, commandeering a Shuttle launch may become a matter of necessity, as retaining the services of the STS until 2030 is one of several options now being evaluated by NASA as a means of filling the void left by the cancellation of the National Launch System (NLS) last year.

Under the GD plan, each lunar mission would begin with the launch of a Shuttle carrying in its payload bay a Lunar Excursion Vehicle (LEV) and a crew return capsule. During flight day two, the Shuttle's crew would use the remote manipulator arm to mate the lunar crew capsule to the LEV. The following day, two astronauts would don spacesuits and transfer over to the lunar vehicle. In the meantime a Titan IV booster would place a fully laden Centaur upper stage into an orbit close to that of the Shuttle. The LEV would then be deployed in order to rendezvous and dock with the Centaur stage. With the orbiter in close attendance the lunar crew would check out the systems of the capsule/LEV/Centaur combination, before igniting the Centaur's main engine to boost the vehicle towards the Moon.

The four legged LEV - a new vehicle built specifically for the task - doubles up as both the descent and ascent stage. The LEV has a dry weight of 3,200 kg and carries 17,140 kg of liquid oxygen/liquid hydrogen propellant in its fuel tanks. The crew return capsule would be a scaled down version of the Apollo Command Module, having in this instance a dry weight of 3,450 kg. At the end of the mission the capsule would make a direct re-entry into the Earth's atmosphere followed by a splashdown at sea in the same manner as Apollo.

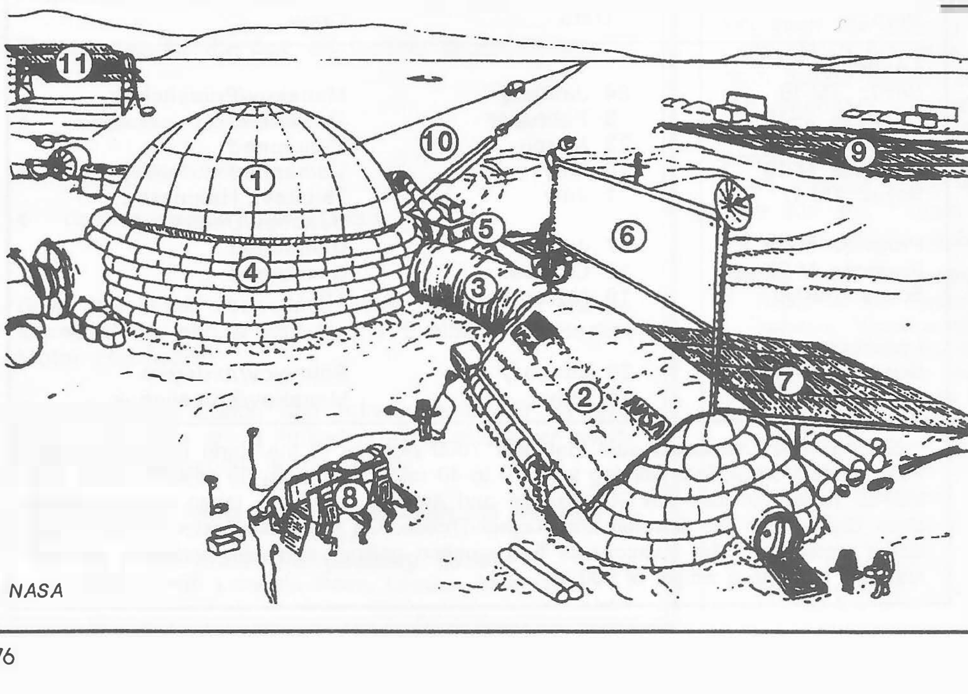
The Centaur Trans Lunar Stage would be based on the vehicle which has seen over thirty years of continuous service as an upper stage to both the Atlas and Titan launch vehicles. However, the version used for the lunar mission would use a single uprated RL-10 engine, unlike all previous versions of the Centaur which have each used two RL-10's. GD is considering the change as a means of improving the overall reliability of the Centaur, which has twice failed in recent years due to engine malfunctions (See ***Spaceflight***, March 1993, p.100).

GD's proposal to launch a liquid fuelled LEV in the cargo bay of the Shuttle is just one aspect of the ELA plan to have raised one or two eyebrows at NASA. At the time of the Challenger disaster in January 1986, NASA was just a few months away from using the Shuttle to launch two planetary probes which would have been boosted out of low Earth orbit by the Centaur cryogenic upper stage. However, in the safety clampdown which followed in the wake of the accident, it was concluded that the use of volatile liquid hydrogen and liquid oxygen fuels posed unacceptable risks, and cryogenic stages such as the Centaur were - and remain - banned from flying aboard the Shuttle. The issue has not yet been reviewed, and it is questionable whether NASA would be willing to revoke the ban simply to take a fast-track back to the Moon.

Target 1999

If New Start funding were to be granted in the current budget cycle, flights to the Moon could begin in 1999 with the launch of an initial cargo flight

Lunar Base



NASA

to the Moon

Early Lunar Access Programme

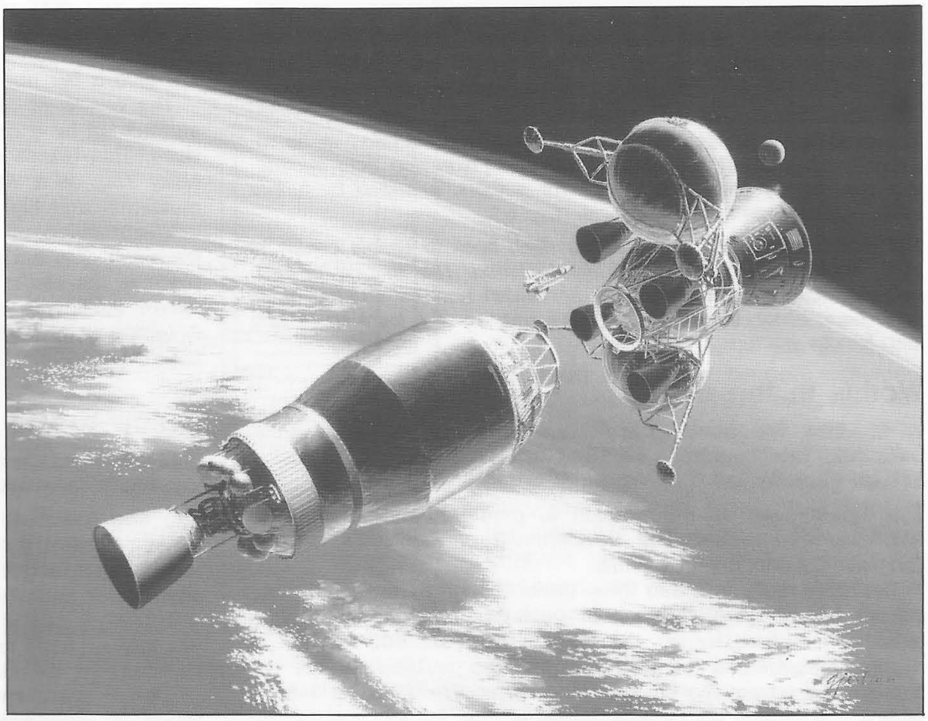
BY DARREN L. BURNHAM
Oxford, UK

to validate the design of the LEV. The 9.7 tonne payload would include equipment such as an airlock, which could be added to the crew habitation facility at a later date, and automatic payloads which would provide an immediate scientific return from day one. Scientific payloads would include a geophysical monitoring station and optical telescope, and a telerobotic rover that would be used to survey potential outpost sites.

This would be followed by the launch of the crew habitation module. To reduce US costs and open the project to international collaboration, GD has suggested that this could be based on the mini-pressurised logistics module which Italy is building for the Freedom Space Station.

The launch of the first crew to visit the habitation module would occur with the third launch. The aim of the mission would be a "moderate" stay of between 14-21 days, in which time the two person crew could become the first to stop over during the long lunar night. Other major objectives of the first crewed mission would include the testing of new generation EVA suits, and a full programme of geological exploration.

Should the decision be taken to continue the ELA programme beyond this point, a second cargo mission would then be flown; its payload comprising of 1.2 tonnes of consumables to replenish the supplies of the habitat, an unpressurised lunar roving vehicle, and optical, Ultra-Violet, and Gamma-ray telescopes. As many as three crewed missions could then follow in quick succession before the more ambitious FLO programme comes on stream.



Lunar Excursion Vehicle (LEV) docks with wide-bodied Centaur upper stage in low Earth orbit.
General Dynamics Space Systems Division

Estimates for the cost of the initial ELA programme (i.e. up to the completion of the third flight) vary from $13 billion using traditional management techniques, to $10 billion for one conducted under the paradigm of "faster, cheaper, better". European participation - with ESA providing both the habitation facility and Ariane 5 launchers to boost the Centaur to LEO, and cooperating in the development of the LEV - would reduce the costs borne by the US to approximately two-thirds of these amounts. As an added incentive, ESA astronauts would be offered seats on some of the missions, allowing Europe to place its first astronauts on the lunar surface at a much earlier date than it could aspire to do by going it alone.

Competition

Answer these simple questions and win a video prize!!

Lunar Base Competition

(Please print or type)

Study the sketch on the opposite page of a Lunar Base and Identify by number (using Nos. 1 to 9):

A. The solar power system for the outpost ____________

B. A thermal radiator for disposing of excess heat ____________

C. What is being used to provide protection from radiation from space ____

D. A permanent habitat ____________

E. An equipment and supplies store ____________

Complete the following two sentences as you consider most appropriate:

(1) The road marked (10) leads to ____________

(2) The solar power collector (11) provides energy for the manufacture of __
____

Those entries that offer the greatest number of correct (or appropriate) answers will be entered for a prize-winning draw.

Complete this form and post it to arrive by first delivery on 3 June 1993.

Return to: The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Title/Name ....

Address ....

....

....

BOOK NOTICES

These notices, compiled by L.J. Carter, are not intended to be reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

Full publication details are given for each book to enable copies to be ordered from a local bookseller, if desired. The address of each publisher also appears, for many items can now be ordered direct from them. If not, they will supply the address of a local agent who can handle matters.

Worlds in the Sky

W. Sheehan, The University of Arizona Press, 1230 N Park Avenue, Suite 102, Tucson, Arizona 85719-4140, USA, 1992, $35 Hardback, $17.95 Paperback.

This book gives an introduction to planetary astronomy with emphasis on the historical development of mankind's fascination with the Moon and planets.

The story really falls into three parts, though all are intertwined as the knowledge gained about each planetary body, in turn, unfolds. The first, by far the longest in years but shortest in results, features the early stargazers who first discovered the planets and covers the whole of the naked-eye era. The second relates the many discoveries following the introduction of the telescope while the third features discoveries made in the space age.

The book places all these things in an historical perspective, giving proper credit to those who first pointed the way ahead as well as relating the numerous false routes which had to be corrected before we could reach the fuller understanding we have today.

The Milky Way as a Galaxy

G.F. Gilmore, I.R. King and P.C. van der Kruit, Marston Book Services Ltd, PO Box 87, Oxford OX2 0DT, 392pp, 1992, £29.95.

This is a comprehensive account of the nature of our Milky Way System, written for readers who already have some general knowledge of stellar astronomy. It stems from an era where rapid advancement has taken place both in the theory and observation of the formation, structure and evolution of galaxies.

The aim is to present a broad overview of our home galaxy, for the night sky gives only the barest inkling of its structure. We can see the encircling Milky Way band and the brightening in the Sagittarius region, indicating its centre, but the stars that make up the constellations are generally within one or two hundred parsecs of us, whereas the Milky Way extends out hundreds of times farther.

The study of other galaxies, in spite of their obvious differences, gives some general indication of what the Milky Way Galaxy probably looks like. The advent of astronomical satellites, bringing the possibility of peering through the interstellar dust, has multiplied our awareness not only of the Milky Way System itself but of the general nature of many of its components.

Unfortunately, from our position in one of its spiral arms, we are unable to see its overall structure and, in many directions, cannot see much at all because of interstellar absorption.

This review of galactic astronomy is by three authors who have collaborated to produce a new synthesis of the forefront of our knowledge about our galaxy - what it is, what is in it and how it might have come to be that way. To this end they have divided their topic into 16 sections, the last listing some of the problems extant today.

Their conclusion is that we live in a fairly large galaxy, probably of type Sb1-11. Our position close to the plane is an unfortunate coincidence that seriously hampers Milky Way studies, particularly in the optical band, though it is favourably placed for the study of external galaxies.

Most prominent visually in the galactic halo are the globular clusters, though they actually account for about 1% of the total halo population.

Our local galactic group consists of two major spirals, ourselves and M31 (the Andromeda nebula), the small spiral M33 and various dwarf systems, of which the two Magellanic Clouds and the four dwarf ellipticals around M31 are examples. There are also a fair number of smaller dwarfs.

The centre of our own galaxy is certainly a disturbed region surrounded by a disc of gas and dust, possibly containing young stars. This blends outwards into the gas and dust layers of the Milky Way as a whole and, in turn, is surrounded by the older metal-rich and high density stars of the central bulge.

Interpretation of many of its observed characteristics is controversial. It is not at all clear as to what violent activity is taking place in the central region. Perhaps it is a tiny black hole. The centre, itself, was identified decades ago as the radio source Sgr A (pronounced sadge-A) and is now designated the Sgr A complex, and complex it is indeed.

Guide to the Sun

K.J.H. Phillips, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1992, 386pp, £19.95.

The Sun has been an object of interest since the time of the ancient Greeks, if not even earlier, but the vast amount of observational data acquired in recent years has led to a great expansion in our knowledge of solar physics.

This book opens with an overview of the history of solar astronomy, charting its progress from the very earliest ideas about its nature to the advent of the Space Age. Ensuing chapters describe our present understanding of the solar surface and atmosphere, its interior and its interaction with the rest of the Solar System, particularly the Earth-Sun system.

How the Sun was born and how it currently relates to other stars, as well as its eventual fate, are also dealt with. The latest developments, including the search for solar neutrinos and observations of high-energy radiation are also described.

Harnessing solar power will eventually become a serious alternative as a source of energy to the burning of fossil fuels. The book considers how this vast potential of solar energy is gradually being realised.

A final section deals with observing the Sun with ground-based telescopes and other equipment, as well as with spacecraft. It includes a short section on solar observations suitable for amateurs.

Interrelations Between Physics and Dynamics for Minor Bodies in the Solar System

D. Benest and C. Froeschle, Editions Frontieres, B P 33, 91192 Gif sur Yvette Cedex, France, 1992, 651pp, $75.

This volume falls into four main areas which cover asteroids, comets, meteors and planetary rings.

The existence of asteroid "families" has been known since 1918 when first discovered by Hirayama, who noted evident clusterings simply from looking at their orbital elements. Work has continued to the present day and has been accelerating of late but, as contributions to the text clearly show, it still presents pitfalls.

The comet section contains two particularly interesting papers, one on the physico-dynamical evolution of ageing comets and the other on the processes in cometary nuclei. The section on meteors deals not only with those visible to the naked eye but ranges down to interplanetary dust and charged particles.

Planetary rings are now known to exist around the four giant planets, through they differ widely from one another. Jupiter's ring, for example, is tenuous and its particles are permanently lost and replenished. Saturn's rings are easily the most extensive system, though some are massive and some almost opaque. Uranus has nine main rings separated by dust bands, whereas Neptune has a very peculiar system of very low optical depth rings which feature incomplete structures described as "ring arcs".

By the very nature of its content, rigorous analyses are applied

to practically all of the objects dealt with so a good mathematical knowledge is a necessary prerequisite for getting to grips with the text.

The Guiness book of Astronomy

Patrick Moore, Guiness Publishing, 33 London road, Enfield, Middx, EN2 6DJ, 288pp, 1992, £15.95.

A good deal has happened since the publication of the 1989 edition of this work. New telescopes have been built, such as the Keck telescope in Hawaii and now the most powerful in the world, new space missions have been launched and, of course, the Hubble Space Telescope has been sending back superb pictures, despite its faulty mirror. There have also been many developments in astronomical theory, ranging from planetary evolution to the origin of the Universe and the possibility of life beyond the Earth.

In this fourth edition, the text has been brought completely up-to-date and many new illustrations added, making it a valuable standard work for both reading and quick reference. The two major sections on the Solar System and stars, respectively, are followed by an extensive Star catalogue, with detailed maps. There are smaller sections on telescopes and observatories, the History of Astronomy and a number of short biographical notes on selected astronomers.

Annual Review of Astronomy and Astrophysics

Volume 30, 1992, Annual Reviews Inc., 4139 Camino Way, PO Box 10139, Palo Alto, CA 94303-0897, USA, 1992, 767pp, $57 USA, $62 Elsewhere.

The Society's Library has a complete run of these annual volumes, the latest of which has just appeared. Each presents a selection of about 20 well-informed authoritative articles on a range of astronomical subjects, reflecting the perimeters of knowledge at each particular data.

This latest addition continues the trend with emphasis on the far reaches of the galaxies and galaxy formation. Cosmic background radiation, x-ray, microwave and radio all contribute their own share of problems and are duly considered, though the contribution to our knowledge of the Solar System consists of one paper only, namely on the Pluto-Charon system.

Pluto, unlike other planets, has not yet been visited by a spacecraft, though studies are underway to rectify this. At present, however, there are many inconsistencies and obstacles to further progress. The origin of the Pluto-Charon system is also most perplexing. One suggestion is that both were members of a once large population of "ice dwarf" planets.

Star Formation in Stellar Systems

G. Tenorio-Tagle, M. Prieto and F. Sanchez, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1992, 573pp, £45.

This book comprises eight excellent reviews, each addressing different observations and theoretical aspects of an exciting field of research which embraces the formation of single stars, groups, associations and super associations, up to and including the formation and evolution of galaxies.

The process of star formation occupies a critical position in astrophysics. An understanding of this field is essential if progress is to be made in solving other fundamental problems such as stellar evolution, galactic evolution and the formation of planetary systems. It is a major area of study which poses many basic questions e.g. the range and efficiency of star formation as a function of time in galaxies, how cloud fragments develop to form clusters and star associations and what parameters control the formation of multiple star systems, as opposed to single stars.

Space

Roy Gibson, Oxford University Press, Saxon Way West, Corby NN18 9ES, 1992, 153pp, £15.95.

Space technology has brought about profound changes in the past few decades for science, business and for the world at large. It has enabled us to explore the Solar System and observe the universe beyond in ways previously impossible. The use of satellites has transformed telecommunications and has made remote observation of the Earth's surface possible, with dramatic effects on a variety of activities from war to weather forecasting. Space is now established as a multi-million-dollar industry.

The author, a Fellow of the Society, provides an authoritative account for the non-specialist of the great variety of human activities in space. He surveys the history of the subject and describes the various systems available for putting payloads into space. After considering manned space flight, space science and other uses of spacecraft, such as telecommunications and Earth observation, he surveys what is being done by the various countries engaged in space activities of one kind or another including space commercialisation. A postscript examines what activities in space may have to offer for the future.

The text is written in the author's customery lucid and non-technical style and a glossary of acronyms is provided.

Guidance and Control 1992

R.D. Culp and R.P. Zietz, Univelt Inc., P O Box 28130, San Diego, California 92198, USA, 1992, 754pp, Hard Cover $120, Soft Cover $90.

This volume is divided into five main sections. The first covers a broad range of topics including system level technology, developments in navigation and attitude determination, advanced analytical and modelling techniques and recent hardware advances. The second develops the theme of new technological advancement and includes Brilliant Pebbles technology, attitude sensors and processing. The third examines the latest advances in robotic controls and the test beds being used to develop these technologies. The fourth is devoted to spacecraft control and flexible body interaction. The fifth and final section covers successes and problems encountered on several missions including Microsat, UARS, ROSAT, etc.

The Protection of Astronomical and Geophysical Sites

J. Kovalevsky, Editions Frontieres, B P 33, 91192 Gif sur Yvette Cedex, France, 1992, 207pp, $48.

Although local arrangements have been made in some cases to protect astronomical and geophysical observatory sites from environmental pollution, the problem is both widespread and long-standing, hence this Pilot Study carried out with the financial support of NATO.

Its objectives were to identify the causes of interference which hamper or might hamper observatory instruments, to establish threshold levels and define methods of reducing interference and, finally, to formulate proposals to protect scientific observatories specifying those most in need.

Much of the electromagnetic spectrum is, of course, best observed from above the Earth's atmosphere, a tendency which will undoubtedly continue. At Earth-level, however, there are other pollutants besides the atmosphere e.g. light pollution from nearby towns. Radio waves may also "fog" the telescope, while more than 7,000 objects larger than 10 cm across orbit the Earth, varying from the equivalent of a bright star down to a 15th magnitude object. These are so numerous nowadays that most photographic plates taken by a large-field Schmidt Telescope will register one or more trails from such objects. This problem, so it is argued, is about to be greatly enhanced with the launch of very large space structures having brightnesses comparable to Venus. These could increase the natural sky glow by around 50 percent. Solutions proposed to some of these problems involve the use of special types of lamps and the design of illumination in such a way that it contributes as little as possible to the night sky. As regards radio astronomy, one proposal is that a set of frequency bands should be internationally approved and set aside for radio-astronomy use alone.

The Andromeda Galaxy

P. Hodge, Kluwer Academic Publishers Group, PO Box 989, 3300 AZ Dordrecht, The Netherlands, 1992, 358pp, £55.

The Andromeda Galaxy, or M31, is the nearest spiral galaxy to us and only one of three or four that can be seen with the naked eye. The fact that it appears as a smudgy point of light was noticed as long ago as the 10th century. The first telescopic view of the Andromeda Galaxy was reported in 1612 but both then and for many years subsequently, "nebulous stars" were regarded simply as curiosities.

Messier's Catalogue (1784) listed over 100 "nebulous objects", the 31st of which was the Andromeda Galaxy. Messier was not so much interested in the objects, themselves, but noted them as part of his comet hunting, so as not to mistake one for a comet. In 1885 a variable object was discovered in the M31 nebula, an object that produced both insight and confusion for decades afterwards. This "new star" was eventually responsible for recognition of the true nature of M31 though by 1923, nearly 20 ordinary M31 novae had been found.

M31, about the size of our own galaxy, still provides intriguing observational puzzles. It appears slightly edge-on, which allows many objects to be studied in detail. For example a recent survey has confirmed that it has at least 355 globular clusters and, probably, its number of open star clusters is roughly similar to those in our own galaxy.

The book is a mine of information about M31 and provides a solid foundation on current knowledge of the galaxy. After several chapters tracing its early history, the discovery of its true nature and modern advances, the main part of the book goes on to examine various individual observational aspects e.g. optical structure, neutral hydrogen content and radio continuum radiation. Further chapters follow on its dynamics, mass and rotation before a detailed examination is given of its individual constituents e.g. globular and open clusters, dust, variable stars and novae (including supernovae remnants) and planetary nebulae. Consideration is then given to its stellar population and a comparison made with our own galaxy. Although not a close match, a comparison of some of the basic properties shows that, in almost every respect, M31 is larger than the Milky Way Galaxy. It seems to be more luminous, redder, more massive and of an earlier type.

Mars

H.H. Kieffer *et al*, University of Arizona Press, 1615 E Speedway, Tucson, AZ 85719, USA, 1992, 1498pp, $65.

Although the scientific literature on Mars is voluminous and already includes several books based on spacecraft images, a comprehensive treatment of the *results* of all space probe exploration has not hitherto been generally available.

Over 100 authors have, therefore, contributed to this book to fill the gap and provide a summary of what is known about Mars, describing both those processes that govern its surface and atmosphere and those intriguing areas where more remains to be learned.

The volume was planned to embrace all information available prior to the recent launch of Mars Observer spacecraft. It was intended to include results of the 1989 Soviet Phobos Mission but this, unfortunately, ended prematurely.

Detailed global, geologic and topographic maps of Mars have already been published by the US Geological Survey* and, because these could not readily be reduced to a smaller scale to allow them to be reproduced in the book they have been added as a separate collection of six maps of the same size as originally published and accompany the text.

The result is an outstanding source book on Mars. It is crammed with updated data and information and includes an extensive Glossary and a detailed Bibliography. Practically everything known about Mars has been included.

**Those who require the maps separately can obtain them from the US Geological Survey, Box 25286, DFC, MS, Lakewood, Col. 80225, USA.*

SOCIETY MEETINGS DIARY

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.

It may occasionally happen that, for reasons outside its control, the Society has to change the dates or topics of meetings. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always recheck the scheduled meetings in the latest issue.

5 May 1993 — 7 pm - 8.30 pm

Results from ERS-1

Dr G.E. Keyte
DRA Farnborough

The European Space Agency's ERS-1 satellite was one of the most complex remote sensing satellites ever launched. Despite its complexity, it has functioned almost perfectly since launch in 1991 and has enabled a wide range of research and application projects to be undertaken.

This paper briefly describes the main characteristics of the ERS-1 instruments and gives an account of their 'history' since launch. Some of the main results obtained from each of its instruments are reviewed, covering both the two microwave instruments (the Active Microwave Instrument and the Altimeter) as well as the instrument provided by the UK, the infra-red radiometer (ATSR). It will conclude by reviewing the future development of microwave remote sensing satellites after ERS-1.

14 August 1993

48th Annual General Meeting

The 48th Annual General Meeting of the Society will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, on Saturday, August 14, 1993 at 12 noon. Details of the Agenda will be published in due course.

Admission is by ticket, available to Corporate Members (i.e. Fellows of the Society) only, who should apply in good time enclosing a stamped addressed envelope.

Council nomination forms are obtainable from the Executive Secretary. These must be completed and returned not later than 12 noon on May 22, 1993. If the number of nominations exceeds the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all Corporate Members.

6 October 1993 — 7 pm - 8.30 pm

Microsatellites on Micro-budgets

Prof. M. N. Sweeting

The prohibitively high cost of space projects has effectively restricted first-hand access to space to a handful of nations and international agencies. Spacecraft have grown ever larger and more complex and are also taking longer time-scales from concept to orbital operation. Advances in VLSI microelectronics have catalysed a new species of small, low-cost yet sophisticated and highly capable 'microsatellites' - complementing, and sometimes providing an alternative to, high-cost traditional satellites.

The lecture describes the University of Surrey UoSAT microsatellite programme which reviews the key technologies, management techniques and potential applications of small satellites.

SYMPOSIA & CONFERENCES

19 May 1993 — 10 am - 5.15 pm

Electric Propulsion of Spacecraft

This is the latest in a series of technical Symposia of particular interest to UK participants recording important developments in space technology.

The Programme includes: European Electric Propulsion Survey: The Artemis Spacecraft and Mission: Nuclear Electric Propulsion: The UK-10 Ion Propulsion System: The RIT-10 Ion Propulsion System: The UK-25 Ion Thruster: The RIT-35 Ion Thruster.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Advance Registration is necessary.

Registration: Forms are available from the Executive Secretary. Please enclose a sae.

12 June 1993 — 10 am - 4.30 pm

Soviet Astronautics

The symposium is in its 13th year as an event which reviews the space programme of the former Soviet Union. The programme for 1993 will include talks on the following topics: The Biosputnik programme up to 1993; USA-Russian Manned Cooperation 1992-1995: update on the Manned Operations on Mir; Obscure Unmanned Soviet Satellite Missions, and others still to be decided. A Film will be shown including clips never seen before in the UK. There will be opportunities to ask questions of some of the leading experts on the Soviet Space Programme in the West.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Advance Registration is necessary.

Registration: Forms are available from the Executive Secretary. Please enclose a sae.

22 September 1993 — 10 am - 4.30 pm

European Rocketry in the 1930's

As part of the Society's Anniversary Year the History Working Group are holding a Symposium on European Rocketry in the 30's. Contributions have been invited from Germany, France, Russia and the UK. The 30's is seen as a particularly interesting decade in that much theoretical and practical work was undertaken that laid solid foundations for later projects.

Whilst much publicity has surrounded the experimental and theoretical work carried out in Germany an enormous amount was also carried out elsewhere, particularly in Russia. Much of this story has yet to be told.

Advance Registration is necessary.

Registration: Forms are available from the Executive Secretary. Please enclose a sae.

15 - 17 October 1993

SPACE '93: Space Initiatives

This Special Society two-day meeting to commemorate the Society's Diamond Jubilee, 1933 - 1993 will include themes on:

- Overviews
- Exploring the Planets and Beyond
- Space for the Benefit of Mankind
- New Space Concepts
- Ways and Means

For more information see Society News on pp. 156-7. A special rate for the weekend has been negotiated with two hotels.

Advance Registration is necessary.

Details of the Programme, Registration Forms and Hotel Accommodation are available from the Executive Secretary. Please enclose a sae.

VISITS

14 July 1993

Royal Ordnance Rocket Motors Division Westcott

A one-day visit to Royal Ordnance Rocket Motors Division Westcott, formerly the Rocket Propulsion Establishment. The agenda for the day will include three briefings:

- Background and history
- Site operations
- Current products and markets

Solid and liquid propellant motor firing sites will be toured along with a visit to the Exhibition of Rocket Motor Hardware.

Pre-registration is necessary as only a limited number of spaces are available. Registration forms are available from HQ on request.

16 - 22 October 1993

44th International Astronautical Congress

The 44th International Astronautical Congress will be held in Graz, Austria, from October 16 - 22, 1993 under the auspices of the International Astronautical Federation (IAF) and its associated bodies, the International Academy of Astronautics (IAA) and the International Institute of Space Law (IISL).

The Congress will be held at the Grazer Congress (Convention Center Graz). This is an excellent facility, centrally situated in the heart of the old town.

Hotel rooms have been reserved at special rates for Congress participants and guests. Most hotels are within walking distance of the Grazer Congress.

Details of the Programme, Registration Forms, etc. will be available from BIS HQ shortly.

LIBRARY

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. The Library will also be open on Saturdays between 10.00 am and 1.30 pm on the following dates:

21 August
18 September
23 October
20 November
18 December

Membership cards must be produced.

2 WAYNE

JOIN THE BRITISH INTERPLANETARY SOCIETY

When you join the British Interplanetary Society *Spaceflight* will be mailed directly to your home address each month, hot off the press.

As a member of the Society you will become part of a worldwide organisation which promotes space and astronautics and be able to attend the wide range of Society meetings, visits and other special events. Members also receive discounts on Society publications and entry to symposia.

This offer includes either a FREE *High Road To The Moon,* a 120 page book containing pictures by R.A. Smith *or* an official Society pin-on lapel badge *or* a voucher that entitles you to £5 OFF any title In the BIS Video Collection.

APPLICATION FOR MEMBERSHIP OF THE BRITISH INTERPLANETARY SOCIETY

I apply for Membership which will include a subscription to ***Spaceflight*** and one of the following special offers:

High Road To The Moon, a 120 page book containing pictures by R.A. Smith ☐ †
or a voucher worth £5 off the price of any title in the BIS Video Collection ☐ *
or an official Society pin-on lapel badge ☐ †

I enclose £35 (US$70) for a 12 month subscription from January-December 1993 ☐

A special reduced rate of £26 (US$52) is available for those under 22 or over 65 years.

Full Name (please PRINT surname first)	**Title**
Postal Address	**Date of Birth**
Professional Affiliation & Address (if applicable)	**Job Title or Position**
Signature **Date**	***Application constitutes acceptance of the Society's Constitutional Rules***

Send to: The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, England

NB Videos available in VHS PAL format only. *Offer closes 30 June 1993. † While stocks last.

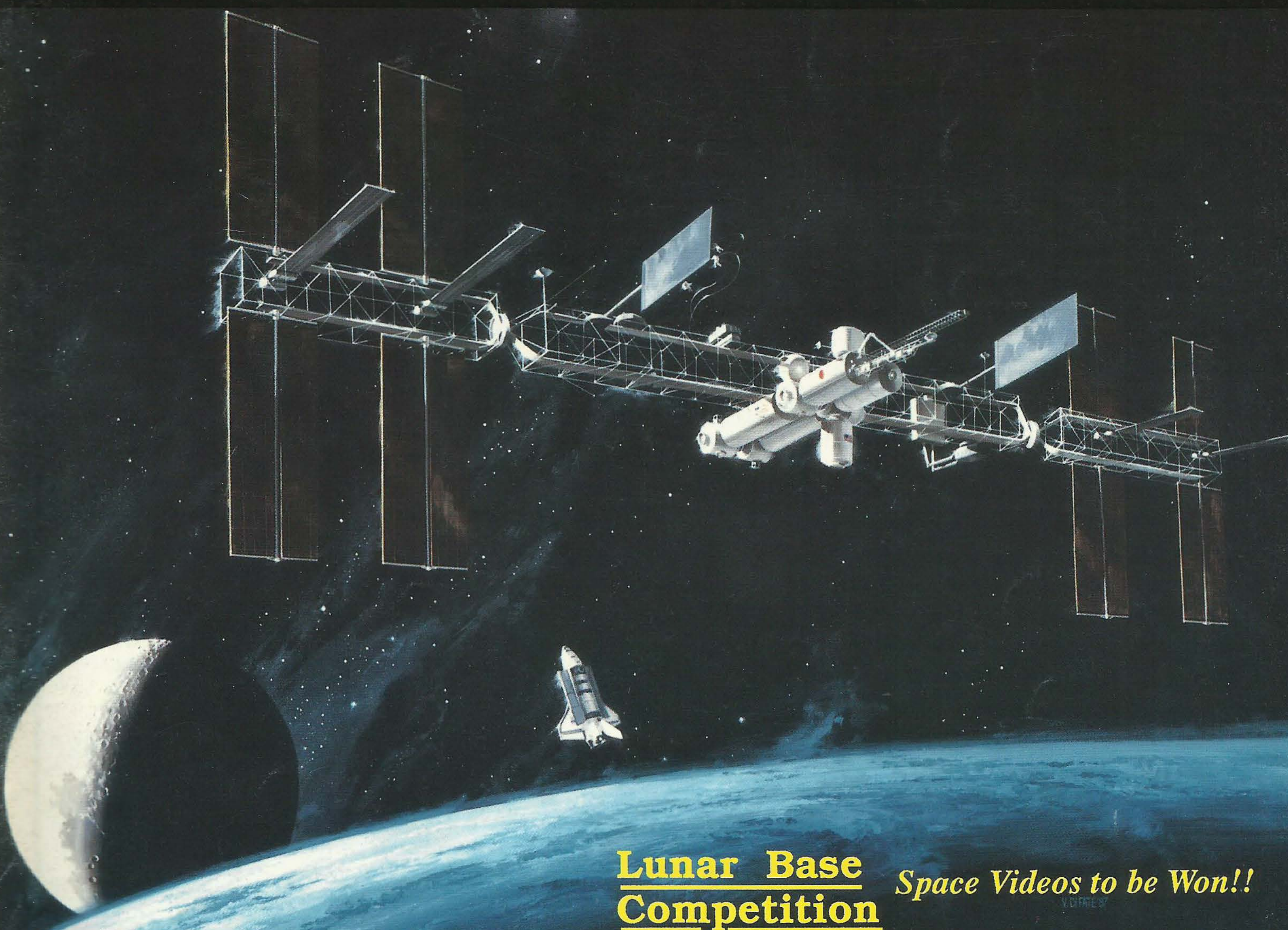
A Publication of the British Interplanetary Society June 1993 Vol. 35 No.6 US$3.50 £1.70

Spaceflight

The International Magazine of Space and Astronautics

Crucial Space Collaborations

for Combatting Space Debris ● Space Station ● Solar System Colonization



Lunar Base Competition

Space Videos to be Won!!

- **ASTRONAUTS:** Train at BAe; Suffer Back Pain; Gemini Honours
- **SHUTTLE:** Link-Up with Schools; To Florida to Watch a Launch
- **ESA:** Science Projects Latest; Space Station Crew Simulation
- **PLANETARY PROBE MISSIONS: HUBBLE SPACE TELESCOPE**

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* * *

Spaceflight is distributed in the UK and overseas through newsagents by COMAG Specialist Division, Mercury Centre, Central Way, Feltham, Middlesex TW14 ORX Tel 081-844 1000 Fax 081 751 266

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Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

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Spaceflight

The International Magazine of Space and Astronautics

Published By The British Interplanetary Society

Vol. 35 No. 6 **JUNE 1993**

Front Cover: An artist's impression of the Freedom International Space Station. *NASA*

Crucial Space Collaborations

International organisations and agencies continue to play a vital role in the development of space.

International cooperation is the main ingredient of many successful space projects.

The international process of space exploration is constantly being extended.

* * *

But in some instances the 'past' has not always created the right environment for the 'present'.

More serious is the situation where 'the past has to be overcome'.

Here political change as well as 'vision' may be needed and the international dimension may become a crucial factor.

* * *

In this issue, three areas are identified where international collaboration is recognised as crucial:

- **Space Debris p.182**
  'The space debris problem can only effectively be solved by international cooperation'
- **The International Space Station p.186**
  'If the Station is to be successful, all parties must contribute with maximum effectiveness'
- **The Starship as an Exercise in World Government p.188**
  'World Government is a prerequisite to Solar System colonisation, and thus to interstellar travel'

Space

The Problem of Protection:

In the early days of space exploration, one of the great fears was that spacecraft would be destroyed by collision with meteoroids. The natural meteoroid flux is now known to be less than what was thought and the possibility is growing that spacecraft around the Earth may be damaged by an increasing amount of artificial space debris. At this time, when the problem is gaining international recognition, *Mr H. Heusmann* reviews our knowledge of space debris and the hazards that it presents.

BY H. HEUSMANN
ESTEC, The Netherlands

What is Space Debris?

Man has been ejecting objects from Earth into space since 1957 in such a way that they stay there, orbiting the Earth. Launch rockets consist of stages, the first stage for lift-off being the largest and the last, usually the 3rd or 4th, being the smallest. The objective is to get rid of burnt-out rocket fuel casings by stage separation and so avoid carrying unnecessary mass into orbit. Earlier stages fall back to the Earth usually into the ocean, since their velocity is not high enough to enable them to continue orbiting. The last stage, which delivers the satellite, by necessity however, stays in a stable orbit even though it has then become a useless piece of equipment. Since nothing made by man lasts forever even the satellite will stop functioning after a period of time and also become useless.

Manned vehicles, like the early Vostok and Voskhod capsules from the former USSR and the Mercury and Gemini capsules from the USA or, since April 1981, the Shuttle all returned to Earth by using retro-rockets to re-enter the atmosphere on a precise path and land accurately on water or land. Manned Space Stations, like Skylab, Salyut, Mir or the future International Space Station Freedom, will also eventually return to Earth. Because of their large solar array surfaces their velocity is reduced continuously by the residual atmosphere, even at altitudes of 400 km to 500 km, until they literally fall out of the sky, as did Skylab in July 1979 on the coast of Australia.

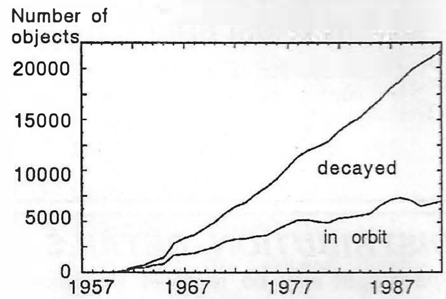


Fig. 1 Number of trackable objects in Earth orbits as a function of time.
University of Braunschweig

The orbital lifetime of a station can be prolonged by periodic boosts to lift its orbital altitude but the necessary additional propellant for the rocket motors must be carried to the station by regular supply flights, as is done by the Progress vehicles to the Mir station and is proposed for the Shuttle to the Space Station Freedom.

Whereas Buran, the Russian Shuttle-like vehicle, and the US Shuttle both land on runways, the reentry crash zones of the space stations cannot be predicted and remain speculative up to, literally, the last hour.

To date, some 3,400 launches have occurred since Sputnik I in 1957. An equal number of satellites and upper stages populate space, or have populated space for at least some time. Various upper stages and some satellites have been cleaned from near-Earth space by the decelerating effect

Space Debris: Common Misconceptions

Misconception 1: Space debris is a larger problem today because the international space launch rate has increased.
On the contrary, the catalogued debris population has steadily grown while the international launch rate has remained stable.

Misconception 2: The hazard from orbital debris is well defined.
On the contrary, there is a significant uncertainty (orders of magnitude) in the probability of collisions and the effects of debris impacts.

Misconception 3: The cessation of satellite breakups will solve the orbital debris problem.
On the contrary, the hazard from debris already residing in space, coupled with other sources of new debris, such as debris resulting from space operations, will still create a concern for many years to come even if no more satellites were to fragment in the future.

Misconception 4: International laws and treaties help to control the growth of the orbital debris population.
On the contrary, though all parties agree in principle on the need for formal laws or treaties, none as yet has any impact on the control of orbital debris.

Misconception 5: The former Soviet Union, which was responsible for more than 70 percent of all space launches and satellite breakups during the past 25 years, has historically been the source of the majority of the Earth's debris population.
On the contrary, The United States and the former Soviet Union were equal contributors to the present catalogued population.

Misconception 6: Debris from weapons testing space is a major component of the Earth's satellite population.
On the contrary, the 12 breakup events associated with space weapons tests are responsible for less than 7 percent of the catalogued population.

Misconception 7: Bumper shielding can easily protect a space system from the debris environment.
On the contrary, a bumper system can protect a satellite from only a portion of the debris environment

Misconception 8: People are likely to be killed by fragments of re-entering debris.
On the contrary, the chances of being struck by debris are extremely small.

Source: Office of Technology Assessment Report on Orbital Debris

Debris

Space Station Concerns

of the residual atmosphere and, through optical and radar observations, it has been established that some 22,000 pieces have orbited around the Earth of which 15,000 pieces have decayed (fig. 1). All remaining 7,000 pieces, except for about 350 operational satellites are really space junk and it is only a matter of time before presently operational satellites join them. By that time however, so many more satellites will have been launched that the amount of junk will continue to grow.

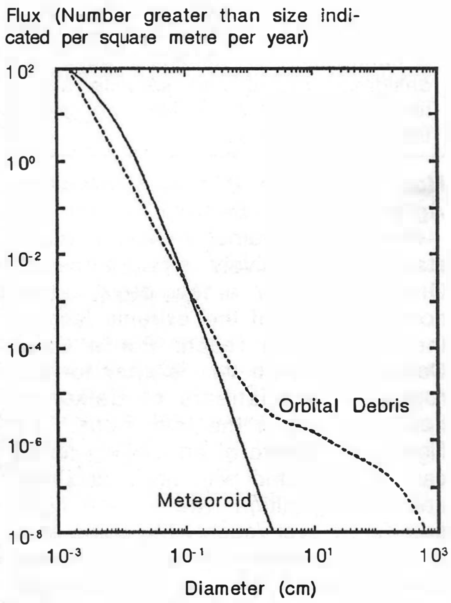


Fig. 2 Comparison of meteoroid and orbital debris fluxes as a function of size predicted for 1995 at an altitude of 500 km and an orbit of 28.5 degree inclination with a solar radio flux of 97.0.
NASA SSP 30425 Revision A

A question posed is why many more pieces of space debris exist than the sum total of launched satellites and upper stages? The prime reason is the explosion of upper rocket stages. After some time in orbit, in one case as long as 20 years after launch, the valves and lines of the liquid rocket fuel corrode and the rocket explodes and this process, unfortunately, is very effective in producing hundreds and thousands of small pieces of debris, ranging from sub-millimetre dimensions up to several metres. Examples are Ariane and Delta launchers and Cosmos 862.

Another process in creating space debris is the collision of a piece of space debris with a satellite. Two suspected cases are Cosmos 1275 and Transit 4-A. The fear expressed by NASA space debris scientist, Donald Kessler, is that existing space debris will collide with other space debris so that, even without addition of more satellites and upper stages, the number of space debris particles may grow into an avalanche effect.

Satellites have sometimes been exploded deliberately, e.g. ASAT chaser and Cosmos 699. Smaller in number are lens caps or protection lids of satellites, which are jettisoned, or tools and equipment lost by astronauts in activities outside their vehicles.

In total, the number of space debris particles versus their diameter can be seen in the Table. The flux versus diameter is shown in fig. 2. The total mass of space debris is more than

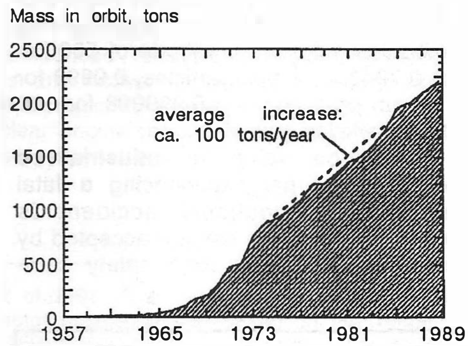


Fig. 3 Total mass of payloads and upper stages in LEO. *University of Braunschweig*

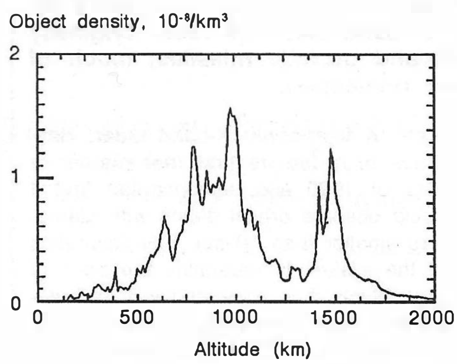
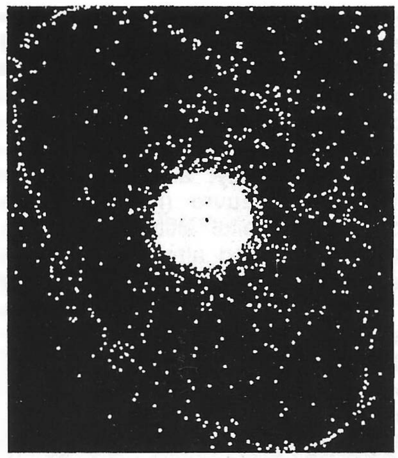


Fig. 4 Spatial density as a function of altitude of the population represented by the USSPACECOM two line elements of 1.1.1992. *University of Braunschweig*

Particle Diameter and Number of Particles. *ESA/ESOC*

Particle Diameter (cm)	Number of Particles
0.1 - 1	> 3,500,000
1 - 10	> 17,500 (20,000-70,000)
> 10	> 7,000 (catalogued)



2,000,000 kg, (fig. 3).

Other parameters characterise space debris, e.g. altitude distribution and velocity, (figs. 4 and 5). Velocity is

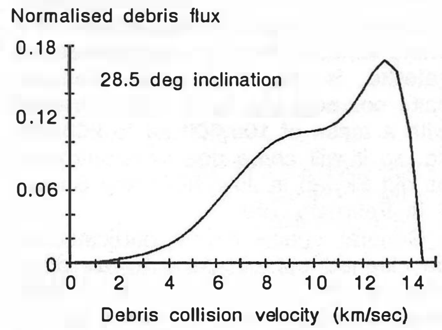


Fig. 5 Normalised debris flux as a function of the collision velocity.
Rockwell International

plotted as the velocity of a particle approaching a spacecraft. The velocity of a spacecraft in low Earth orbit is about 7 km/sec. A particle travelling alongside the spacecraft has zero velocity, whereas a particle heading on to the spacecraft has a velocity of 2 x 7 km/sec. The last important characterisation is the angle of incidence on to a spacecraft. Since most debris orbits with low eccentricity, it approaches the spacecraft in a horizontal plane. A lack of impacts on the front and rear of a spacecraft arises because debris from the front must orbit at a lower velocity than the spacecraft, i.e. it must have a low perigee, which makes it extremely short-lived, whereas debris from behind must have a high apogee, which is rare. So, debris mostly comes from the side and combines with the spacecraft's velocity to determine its apparent impact angle on the spacecraft. Nearly all space debris has been assumed to be of aluminium, which has a density of 2.8.

For completeness, meteoroids must be mentioned. Their flux is by now much smaller than the flux of space debris (fig. 2).

Why is Space Debris Dangerous?

Large space stations lose altitude relatively quickly as a result of the air drag of their relatively large solar ar-

rays. The density of the residual atmosphere varies with day and night and, particularly, with the eleven-year solar cycle. With the increase of solar activity the residual atmosphere heats up and becomes denser. At times of low solar activity, a given standard reboost manoeuvre (resulting in an increase of orbital altitude of 50 km) must be repeated after 100 days, but the interval might decrease to 75 days at times of high solar activity. An alternative is to fly higher during such periods, where the air density is again lower. Whatever strategy is chosen, any space station will become obsolete in due course. If it takes 20 Shuttle launches to assemble the future International Space Station Freedom in orbit, it will take also 20 Shuttle flights to bring the station back again. This is not likely to happen for economic reasons. Firing a retro-rocket for precise re-entry, as for a manned capsule or a photo-capsule from a reconnaissance satellite, is technically and economically not possible for a space station with a mass of 100,000 kg to 200,000 kg, so it will come down uncontrolled, as did Skylab in July 1979 and Salyut-7 in February 1991.

General space debris particles will be cleaned out of space by air drag, although that could take tens or hundreds or thousands of years due to their higher mass to cross-section ratio. This prolongs the chance that they will hit a spacecraft. In the case of a manned spacecraft or space station, particles can pierce holes into pressurised laboratory or habitation-modules or into high pressure tanks. The consequences could be loss of air and pressure, the burst of a module, loss of attitude stabilisation of the station or physical disintegration of a major part of the station.

The two space stations so far returned viz Skylab and Salyut-7, did not cause casualties. In the case of Skylab, NASA had intended to extend its orbital life by attaching a boost motor to it but higher-than-expected solar activity causing the orbit to decay faster, plus delays of the first Shuttle launch, prevented this plan from being executed. When it became clear that Skylab would crash, NASA changed the attitude of Skylab with respect to its velocity vector, using some of the remaining nitrogen propulsion gas, in order to utilise the effect of the air drag and control the crash point to some degree.

One can evaluate the probability of casualties being caused by a crashing station by overlaying the area of the debris cloud over habitated areas within the plus/minus 28.5 degree latitude (equal to the location of the Kennedy Space (launch) Center) and relating it to the uninhabitated and ocean areas.

The probability of a space debris particle not hitting a space station of 200 m^2 cross-section (pressurised modules only) at an altitude of 500 km is 0.7948 for 1 mm particles, 0.9993 for 10 mm particles, and 0.999998 for 100 mm particles per year.

A global value for industrialised countries of not experiencing a fatal road or occupational accident is 0.9995 per year, a risk not accepted by society, as regular road safety campaigns show.

US and Japan Agree on Space Debris

An agreement to launch a joint project to strengthen ground-based monitoring of space debris and to prevent its accumulation was signed by the Japanese and US governments in November 1992. They agreed to enlist cooperation from European and former Soviet nations in setting up the project on a global scale by April 1993.

The cooperative agreement includes plans to strengthen ground-based observation of orbital debris and develop tests to simulate collisions between a space station and debris.

National governments intent on promoting outer space development have not until recently placed priority on the monitoring and control of space debris. The US government has released a handbook recommending ways of designing rocket and satellite systems that reduce or eliminate the creation of space debris.

How Can One Obtain Protection Against Space Debris?

Protection against a falling space station is relatively straightforward. One moves, for a few days, either north or south of the extreme latitude the station can reach. For a Cape Canaveral launch this is easy for Europeans. The latitude of Baikonur, however, lies in the mid fifties. The flight path pattern of an orbiting object can be predicted with great accuracy and the repetition rate for the flight path to be over roughly the same area is at least a couple of days, so for the critical time of an overpass one just moves some tens of kilometres sideways from the trajectory.

Protecting a space vehicle against space debris is difficult and complex and also a fairly recent task. For the Apollo capsules protection from meteoroids was a design consideration but the Shuttle was not designed with a particular protection from space debris in mind, although its double wall crew cabin gives quite an effective protection. Also, the relatively short exposure time of the Shuttle to the debris environment, of days compared to tens of years for the future Space Station Freedom, helps to limit the risk of damage or loss. However, the risk is expressed as a probability of a catastrophe or otherwise. The very high number of particles beyond the 7,000 catalogued space objects, whose trajectories are known and can, therefore (at least theoretically) be avoided, is only known statistically. These objects can be lethal just the same. Objects of 10 cm to 30 cm in size are the smallest, which can be detected. The 1 cm to 2 cm size of particle is the largest for which the Space Station is protected.

Radar Tracking of Orbital Data

For more than 20 years, NORAD (North American Aerospace Defense Command) has maintained responsibility for cataloguing the Earth's orbital debris population. Using L- and C- band and VHF radar originally designed to detect high-flying aircraft and ballistic missiles, much of the orbital particle population remains unmapped.

In 1989 NASA and USSPACECOM completed an agreement to develop a ground-based radar programme capable of examining the debris population density of objects of 1 cm or greater diameter at altitudes up to 500 km. When complete, it will provide much needed data for:

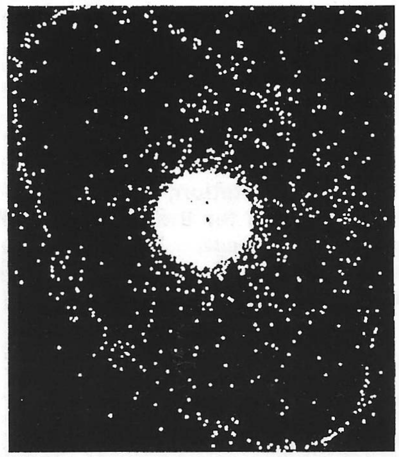
- extended duration shuttle orbiter;
- long-duration extravehicular activity by astronauts;
- future modification to Space Station Freedom shielding;
- determination of source debris;
- effectiveness of operations designed to minimise debris.

USSPACECOM has made near-term observations of space debris using the exiting Haystack antenna in Massachusetts. A high-power X-band radar, Haystack provided its first test results in May of 1990 and demonstrated that it could observe orbital debris with diameters smaller than 10 cm. Full calibration of the system to determine the sizes of the objects it is observing will be completed during the next 12 months with the flight of ODERACS (Orbital Debris Radar Calibration System) on the space shuttle.

NASA and the US Air Force have recently completed the Haystack Auxiliary (HAX) Radar at Millstone Hill, Massachusetts and a copy on Ascension Island. HAX will gather information in the Ku-band, and in conjunction with Haystack, will provide enhanced debris data.

Source: EnviNET News, NASA

First European Space Debris Conference



At the Initiative of the European Space Agency (ESA), the First European Space Debris conference was held in Darmstadt, Germany from 5 to 7 April 1993 gathering together 251 world experts from 17 countries including China, India, Japan, Russia and the USA.

Many questions were raised concerning how much debris and how many meteoroids are in near-Earth orbit, the computer tools available or under development to predict the growing number of natural and man-made objects, the analysis of material returned from space and the risk run by satellites in general and in geostationary orbit in particular. Presentations ranged from the orbital debris environment projection for the Space Station Freedom to the impacts detected on the Long Duration Exposure Facility. A round table discussion explored the possibilities offered to control and regulate debris.

The main conclusions of the conference were that:

Ground based observations with radar and optical facilities reveal the existence of about 7000 objects in space, which do not represent an immediate danger.

However, adequate actions have to be taken in order to keep the debris hazard for manned and unmanned missions within safe limits. Of most concern are the long-term prospects of the debris hazard, particularly in those regions in space which are most heavily used, e.g. low Earth orbit (900-1500 km) and the geostationary orbits (at about 36,000 km).

The clean up of debris is neither technically practical nor economically feasible. The thrust of the action must be towards preventing the creation of debris.

Several preventative measures have been identified and implemented in space activities, such as releasing residual propellant in rocket upper stages to preclude a subsequent explosion from generating many fragments, and the reorbiting at higher altitudes of geostationary satellites at the end of their mission in order to avoid collision with operational satellites. Further possibilities include destructive re-entry into the atmosphere to burn up the spacecraft or selection of orbital parameters to limit the lifetime.

The space debris problem can only effectively be solved by international cooperation.

Bilateral discussions between space agencies on the debris issue have taken place since 1987. Furthermore, on the occasion of this First European Space Debris Conference, the first multilateral discussions among representatives of NASA, the Russian Space Agency, Japan and ESA took place in Darmstadt to present results of their research activities, to identify possibilities for cooperation and to discuss methods for debris reduction.

Space Debris *by H. Heusmann*
(continued)

In a collision of two cars, velocities are in the order of tens of kilometres per hour and the energy to be absorbed ranges from 10^5 Nm to 10^6 Nm, equivalent to the impact energy of a 1 cm aluminium particle at 13 km/sec, the most likely impact velocity. A 10 cm diameter particle has the impact energy of 1,000 cars crashing into each other at a speed of 100 km per hour.

In an experiment employing typically a two-stage light gas gun one can throw a small aluminium sphere with a velocity of 3 km/sec to 6 km/sec against a thin wire. The thickness of the wire is really immaterial. The aluminium particle upon hitting the wire will disintegrate into a cloud of small particles, leaving the wire broken or unbroken. Exploiting this phenomenon, one could attempt to cover the pressurised modules and high pressure tanks with a mesh. This is difficult to keep in place through the acoustic noise during launch. The mesh can be approximated by a thin metal shield (< 1 mm). Experiments show that two shields are more effective than one of double thickness at the same distance from the surface to be protected (the pressurised module wall). A key parameter for effective protection is the distance of the shield from the surface to be protected. On penetration of the shield by a particle, a debris cloud is formed with a given spray angle. The pressure and particle loading of the next shield or module wall decreases as the distance between the two is increased.

On the International Space Station Freedom programme, NASDA and ESA agreed to increase the diameter of their pressurised modules which form part of the International Space Station Freedom in order to accommodate a NASA designed payload rack to facilitate easy access to the station through rack exchange by the international payload community. This is a noble enterprise. However, the available space for shielding on the ESA provided Columbus Attached Pressurized Module shrank from 200 mm to 120 mm and, with it, its protection effectivity.

There is a very tight limit to increasing space station protection by shielding. Considering the debris flux in the diameter range of 1 cm to 10 cm, the flux curve has a very shallow slope, (fig. 2). In other words, there are not very many particles of that size. Shielding the station against 10 cm particles, as compared to shielding it against 1 cm particles, makes an enormous, practically unrealisable difference in shielding mass, whereas it only makes an insignificant difference to the probability of the station not being seriously hit because of the small number of debris in that size class. This statement is oversimplified for clarity.

Recognising these facts, tells the designer to look for mitigating effects elsewhere. The presently foreseen shielding does not quite meet the value of no catastrophe probability, which is set as a requirement for the space station, and which NASA and the International Partners (Canada, Japan and ESA) are determined to achieve.

What constitutes a truly catastrophic event needs to be defined. Not just any hole is lethal. Racks mean additional protection against the speed of losing the atmosphere in the case of a hole in the pressurised module wall. The crew must be assisted by an alert system to indicate when and where a leak has developed and how critical it is. They must be helped by an evacuation system showing the escape route through lit up paths, as in an aeroplane. The crew must be helped by extending the times for the evacuation of modules and the rescue of disabled crew members by injecting a respirable atmosphere.

If the Assured Crew Rescue Vehicle is approved as a programme, with the aim of rescuing a crew which would otherwise be stranded, equivalent efforts must be made to allow the crew to actually reach and make use of the ACRV.

International

Reconceptualize Not Redesign:

The Space Station, according to the most recent pronouncements from the Clinton Administration, returns to the drawing board for the fourth redesign in as many years. Again, the project confronts an economic reality that grows increasingly bleak. In this article *Joan Johnson-Freese* and *Roger Handberg* take a timely look at the factors that have been dogging the progress of this major international space project and the steps that need to be taken to revitalise it with the vision which the project originally had.

Sizewise, the Station is well on its way to being reduced to a Quonset hut in space. Scientifically, the Station offers less and less as the power capabilities are scaled back proportionally. Emotionally, within the United States, the Station has declined from the next big step in the great human adventure in space to essentially a jobs programme, particularly for economically battered California.

Producing jobs is not an insignificant social achievement to be sneered at by space advocates. But the down side is that when jobs are the key driver for a space project, a great deal of effort is often expended for little tangible return other than those jobs. That the Station has indeed become primarily a jobs programme in the United States is indisputable. When the outline of the latest redesign was announced by NASA Administrator Dan Goldin, the headlines in the FLORIDA TODAY newspaper (located in Cocoa, Florida - home of the Kennedy Space Center) read "NASA to cut space station jobs." Mention of the substantive aspects of the redesign were scant and toward the end of the article. The focus of public interest was clear.

A more interesting interpretation of President Clinton's redesign mandate is that it represents a subtle way of cancelling the Station without appearing to do so. By slashing by possibly half the jobs produced by the Station, Clinton strikes directly at the political coalition that has sustained the Station for a decade against strong opposition. If the Station's political support ebbs significantly in Congress, cancellation will come as a matter of course while the President appears still supportive of the program (a 1992 campaign promise). Therefore the actions of the Administration over the next ninety days are critical. If the Administration takes it upon itself to actively and aggressively "sell" the redesign (which is the closest attempt at a reconceptualization so far), then the sincerity of its support for the Station will ring true. If, however, the Administration sits back and silently watches NASA bear the burden of trying to hold the Congressional and industrial coalition together, then one must question the Administration's real intentions. Hopefully the former will occur.

The good news is that for the first time there seem to be glimmers of recognition that merely taking an eraser to the Station blueprints will not be enough to salvage the project politically, economically, technically or scientifically. That the redesign team will supposedly consider asking the Russians to participate and that the international partners will take part is a step in a new direction, as is the directive that the Station should be accessible by launchers other than just the Space Shuttle. That operations costs should be cut is interesting, since just what the operating costs will be is a topic NASA has avoided like the plague. The redesign is to be completed, as often in the past, within ninety days. Theoretically, the time limitation will keep up project momentum. At this point that consideration becomes almost nonsensical. More pragmatically, the time limitation on redesign limits the detrimental impact on affected jobs. Hopefully, however, the time limit will not limit the redesign considerations to band-aids rather than true fixes.

If the Station is to be successful, all parties must contribute with maximum effectiveness.

As the Space Station has become the centerpiece of American, and international, space efforts for the foreseeable future the monetary commitment involved compared to likely available funding means that something significant must come of the enormous expenditure of scarce fiscal and human resources. There is likely to be comparatively little else made available for other equally promising programmes and projects. The Station must demonstrate that it is more than merely a nice place for the Shuttle to visit on occasions. According to Administrator Goldin, President Clinton is "holding us (NASA) accountable for placing a meaningful scientific facility in space. He has placed us in charge of our own destiny." Interesting that in order to follow that directive NASA may have to look not just to the future, but also to the past.

Reconceptualizing the Station

Werner Von Braun's famous early nineteen fifties wheel in space, popularized by Disney in a short feature and a prototype for future space planners, was to be the hub of space activity in the near Earth region. Space Station Freedom in its original conception also bid for that broad type role, although not utilizing the wheel design, even though many people argued at the time of the decision that several smaller, Skylab-type stations would have actually been both more economical and functional. The various mandated designs have grappled with technical problems but, more critically, with the cost problem since the rationales do not justify the expense.

At each redesign stage, something seen as important earlier has been eliminated or reduced in size or function in order to meet constantly changing requirements imposed by the White House, Congress, NASA, or other groups in varying combinations. The logic of each step in the redesign process has been both understandable and likely acceptable. The cumulative result, though, is a project whose conceptual coherence has been compromised and whose practical usefulness is in real doubt. Each redesign has encompassed a degradation in Station performance and flexibility. The issue is how much performance can decline until the project is no longer viable. Nobody ever seems to be pleased with the results of the earlier redesigns, either substantively or financially. Although intended to bring down the Station costs, NASA estimates for construction and bringing it to a permanently-manned status have recently reached $31.1 billion, from the original $8 billion.

As to who is to "blame," there is much finger-pointing, very little self-examination, and nobody seems to take criticism very well. In actuality there is plenty of blame, or acceptance of responsibility as it used to be called, to go around. President Reagan first gave the nod for the Space Station in his 1984 State of the Union address, and then promptly forgot about it in favour of his pet Star Wars project. NASA then set about designing a Station, primarily driven by political plausibility rather than scientific soundness. Congress supported the idea of a Station, but because of NASA's apparent design indecision, quickly fell into a pattern of deadly stretch-outs and micromanagement techniques which extended to allowing eager staffers their shot at designing a space station. NASA, always fighting to return to the glory days of Apollo, responded to all this by underestimating costs and over-managing the project right into financial oblivion. And the American public sat by watching, willing to believe that space is expendable so in these tight economic times it is all right to let this bickering go on.

At this point, delaying or stretching-out the Station's completion yet again has become inevitable. Therefore, taking the time to reconceptualize the project will probably not delay it any more than another redesign, or inflate costs any more. Each redesign has run on a ninety day cycle from requiring the new relook to its expected completion. Even given the personal energy and leadership of the current project managers, what can a new team do in ninety days that others could not have already done in the past? Even

Space Station
The Quonset Hut in Orbit

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given the new parameters of not being entirely tied to the Space Shuttle, and not necessarily having it continually manned, there is still a basic reliance on clever technical solutions to what are clearly more fundamental problems.

The problems the Space Station has encountered since its inception have to a large extent been conceptual rather than technical in nature. The conceptual problem is that there has not been a core concept identified as the Station's purpose. Subsequently when defending the project becomes difficult there has been a tendency to simply redefine the "working purpose" to fit the new situation. This had led to a seemingly endless quagmire of political troubles which one must now wonder if it is possible to overcome. Merely being in space, while satisfying to the ideologues, does not satisfy the people who pay the bills.

What Does 'Reconceptualize' Mean?

Reconceptualizing means simply that one puts everything on the table for real reconsideration and analysis. Obviously, the slate is not totally blank but a complete overview means that all the component parts of the Station become subject to review. What is truly being reviewed is not really the technical components of the Station (although that goes on) but the question of what exactly is to be accomplished by the Station. Once that is clearly delineated again - or perhaps definitively for the first time - the next phase becomes explicitly relating the various technical components back to the overall project.

One might ask, has all this not been done earlier? The answer is yes, to some extent (particularly after the recommendations of the Augustine Commission were made in 1990), but much has happened in the meantime. Since the beginning, the Station concept has shifted subtly to meet possible objectives, a moving target that frustrates both supporters and those more skeptical. Agreement on what you are discussing is the first point from whence all others flow. The more recent redesigns reflect the changing political realities and interactions between NASA, Congress, and the President, meaning that the redesigns were responses to the strongest felt political pressures. Redesign has become the euphemism for reduction. The Station appears on the verge of becoming the Sky Lab *redux*. That is not necessarily bad but if that is the new reality, the effort must be not to just to reduce its size but to make the new product as useful as possible. Despite the situation, goals can be lost fairly easily in the day-to-day pressure cooker of national politics. By reconceptualizing the Station, one recaptures the vision that invigorated the original project. That vision sustained a generation of space station advocates. It is in danger of being lost in the current shuffle of deck chairs on the Titanic that the Station has become politically.

Who Does the Deed?

Truly disinterested knowledgeable parties concerned about space as a serious endeavour are rare but there are likely still a few. One must draw upon that group rather those whose economic or political futures ride on a particular outcome. Those few advised by the more involved and technically knowledgeable would do the work. The President and Congress must come together and bluntly define what is available and what is doable.

Integral to this process is the direct and full incorporation of international participation in the reconceptualization and advising process. As the only real reason, beyond jobs, for maintaining the project that is put forth in the annual "axe the station from the budget" battles before Congress has been the international commitment made to the Station "partners", the partners, junior or otherwise, ought to be treated as true partners. If the Station which allegedly is an international project is to truly become one in fact, then those brave or foolhardy participants must be engaged at every stage. The original process excluded them while the later redesigns have been almost random catastrophes for which the international participants have had little or no advance warning. Cooperation requires involvement, not ultimatums and unilateral actions. If the Station is to be successful, all parties must contribute with maximum effectiveness.

Reconceptualizing means simply that one puts everything on the table for real reconsideration and analysis.

As part of a total reconceptualization, all possible options must be given serious consideration. While the Space Station flies only in dreams, Mir plods toward an uncertain future. If reconceptualization works, using Mir or building directly on its experience should be an integral part of the process. Useful flight experience cannot be discarded just because it was not done here. Continuing the Cold War by other means is more damaging to progress in space than ever before given the finite resources available for such endeavours. National rivalries continue on Earth but their effects can be muted at least in civilian space activities such as is possible here. Possible cooperation using Mir or building on its experiences does not compromise military security for any participant so the opportunity should be taken up as a real option. This consideration requires a more open mind than has characterized thought in the field up to now. The down side within the American political context is the possible loss of jobs (a particularly sensitive matter in these economically troubled times) and the still ambivalent feelings among some policy makers, especially in Congress, as to the political acceptability of such arrangements. Overcoming the past means changing attitudes, a process that takes time and persistence.

Overcoming the past also means clearly recognizing that rationality and cost effectiveness have always played second fiddle to national politics in the Station's design. For example, the Europeans built Spacelab in order to gain experience building pressurized modules with the long range objective that they could possibly build the "cans" for a Space Station, each to be outfitted according to a specific need. Although that would have saved NASA money, the notion was conceptually unacceptable to NASA and politically unacceptable to the US Congress, as it would have given the Europeans too great a role in development of Initial Operating Capability (IOC) equipment and taken jobs from the United States. Further, at congressional direction, Canada's robotic arm was nearly duplicated by NASA at great expense in order to deny Canada added technical knowledge, and hence potential jobs. That premise was clearly laid out in a 1986 letter from the House committee dealing with NASA's authorization request, as the ultimate authority in the American political context is not the President but who ever controls budget appropriations and authorizations in Congress. Money not authorized or appropriated cannot be spent. Clearly, politics, not need or only money, has dictated the redesigns. Such concerns will not dissipate quickly but if the Station is to fly successfully, the effort must begin in a serious way now.

Summary

Pragmatism is reflected here in that the underlying premise of our analysis is that the Station remains a priority not yet subject to cancellation or total reconceptualization out of existence. The effort is in making the Station work not just in getting the metal into orbit but in achieving some actual, although unfortunately still unsolidified, goals beyond that of a jobs programme. Momentum in space continues but the Space Station if seen as a public failure has the potential to blight that progress for a long time. Opportunities arise and must be seized, otherwise the wait can be long until the next time. All segments of the space community must be healthy for maximum world progress. The dream of space is strong, the hope is more fragile. The new US President has the opportunity to lead this international venture into reality, or oblivion.

The Starship as an Exercise in

Part 1 - The Political

If the hypotheses we have here laid down are dismissed as Utopian, that does not mean that they are unnecessary or impractical. For we are so often the prisoners of our old traditions that we do not recognise our presence in a new world. *[1;p661]*

Political preconditions to large-scale space development and colonisation, and thus ultimately to interstellar travel, are identified. It is argued that only the establishment of a federal world government will fully satisfy these conditions.

Introduction

The title of the present paper paraphrases that chosen by Parkinson for his 1974 paper, The Starship as an Exercise in Economics [2], in which he considered the economic implications of interstellar travel. Economics cannot be divorced from politics, however, and we shall argue here that far-reaching political issues are implicit in any discussion of interstellar travel, for both economic and other reasons.

A perusal of the different suggestions for rapid interstellar space flight [3-8] shows that they all necessitate large-scale construction activities in space. Not only must the interstellar vehicles themselves be built in space, but their ultimate sources of energy (hydrogen and helium isotopes for fusion rockets, sunlight for both anti-matter production and laser power) must also be collected there.

Thus, any form of rapid interstellar travel will require the existence of a substantial space infrastructure. This will involve:

- The development of efficient methods of transportation between the surface of the Earth and near-earth orbit (e.g. HOTOL-type spaceplanes and advanced heavy-lift launch vehicles);
- The ability to build large and complicated structures in space (e.g. space stations, space factories, solar arrays, lunar and planetary outposts);
- The ability to tap large quantities of solar energy;
- The extraction of extraterrestrial raw materials (especially from the Moon and from asteroids);
- The capability of transporting these materials around the inner solar system; and
- The ability to process these materials in space.

As it is unlikely that any society will develop this infrastructure solely for the benefit of interstellar exploration, only a space-based civilisation, using the economic potential of the solar system for its own domestic purposes, will be able to afford rapid interstellar space flight [2].

The Political Preconditions

Given that an advanced interplanetary civilisation is a prerequisite to interstellar travel, the political questions concern the changes in human organisation that will be necessary before such a society can develop. At least four important preconditions, which involve essentially political issues, may be identified.

Survival

Technological society must continue to exist. If there is no advanced technology then there will be no space infrastructure and thus no starships. The foremost political precondition for all future technological developments is that the world must be organised so as to preserve its scientific and technological base.

Geopolitical Stability

The timescale involved in developing an advanced space infrastructure will be such that governments undertaking it must be free to sustain major projects for many decades, and perhaps centuries. The organisation of today's world is not conducive to such long-term planning as governments are constantly distracted by a host of domestic and foreign policy issues. If space is to occupy governments to the same extent that they are currently occupied by (say) foreign affairs, these other distractions must somehow be made less urgent.

Resource Availability

Technological society must not only enjoy long-term stability, but must have sufficient intellectual and material resources to devote to the development of a space-based infrastructure. Until extraterrestrial materials can make a significant contribution, material resources must be provided by some combination of global economic growth and a diversion of resources from other sectors of the world economy.

Moral Justification

There are many social, economic and environmental problems in desperate need of attention. If significant resources are to be assigned to space development, rather than to other deserving projects, it will not only be necessary to expound its long-term value but also to demonstrate that it is not incompatible with the solution of these other problems. Unless this can be achieved, any proposal to divert large sums of money into outer space will not be politically attractive.

World Government

In a previous article [9], I argued that the establishment of a world space agency would go a long way towards the creation of a political environment within which the steady development of a space-based infrastructure could proceed. However, although an ambitious international space programme would provide an excellent foundation for the development of a space-based society, this proposal fails to address the other political issues identified above. Thus, it seems that if a major world space programme is to be successfully sustained, it must be underpinned by far wider geopolitical reforms, and I shall argue here that the logic points in the direction of some kind of planetary government.

The creation of a world government would be a very major change in the organisation of human affairs on this planet, and one that certainly will not be made merely to assist in the development and colonisation of outer space. Indeed, all the principal arguments for world government recognised by political thinkers (e.g. Saint-Pierre (1713; popularised by Rousseau [10]), Paine [11], Kant [12], Kerr [13], Laski [1], Wells [14,15], Russell [16,17]), are based on the need to prevent military conflict and divert military resources to more productive ends. These arguments are even more cogent today, as the world becomes aware of pressing social, economic, and environmental problems that can only be effectively managed at a global level (e.g. Brandt [18]). However, even if a world government is established principally for other reasons, we shall argue that it would also greatly facilitate the large-scale development of the solar system, and thereby pave the way for interstellar travel.

We need not be concerned here with the precise institutional form of a world government except to say that we should have in mind a federal structure, within which the presently extant nation-states cede responsibility for global affairs to a higher level. We now consider how this would satisfy the remaining political prerequisites for long-term space development.

World Government
Preconditions

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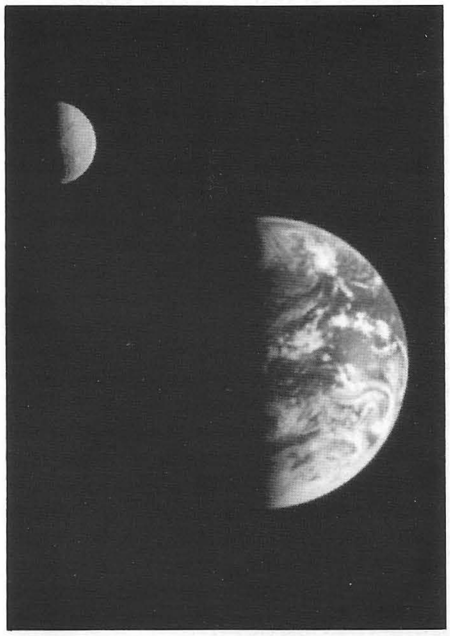

Will a World Space Programme require a World Government?

The Moon in orbit about the Earth taken from the Galileo spacecraft on December 16, 1992.
JPL/NASA

Survival

Although there are possible natural hazards to the future of human civilisation, the most pressing dangers are of our own making, and arise primarily from the belligerent competition of nation-states. Ever since the invention of nuclear weapons this competition has carried the implicit risk of annihilation. This risk now seems lower than formerly, but it is still present, and as long as international relations remain anarchic, with each nation-state acting as judge in its own cause, the long-term future of civilisation cannot be guaranteed in a nuclear age. As the maintenance of an advanced technical civilisation is a prerequisite to the establishment of a space-based society, good prospects for the latter can be secured only by ending the anarchy that currently exists between nation-states. The only way to end anarchy, almost by definition, is to replace it by government, in this case, by world government.

Although a nuclear balance of power has kept the peace for almost fifty years the problem is that, in the present context (and ignoring all other human and moral arguments), we have to guarantee peace for at least as long as a space-based society would take to become fully self-sufficient, almost certainly several centuries. Two hundred years ago Immanuel Kant [19] concluded that

"an enduring universal peace brought about by a so-called balance of power... is a mere figment of the imagination, like Swift's house, whose architect built it so perfectly in accord with all the laws of equilibrium, that as soon as a sparrow lit upon it, it fell in."

The number of times that power balances have failed since Kant's time give no great confidence in their efficacy.

Kant came to the conclusion that the problem lay with the existence of sovereign nation-states. In his essay "To Perpetual Peace" published in 1795 [12], he drew attention to the fact that "the existence of many *separate*, independent, adjoining nations ... is in itself a state of war" (Kant's italics), and, to avoid this unhappy situation, "the right of nations shall be based on a federation of free states" within which "men and nations stand in mutually influential relations as citizens of a universal nation of men".

Following Kant, it is argued here that the evolution of a world government is necessary in order to guarantee the survival of a technological civilisation on Planet Earth.

Geopolitical Stability

Institutional arrangements made to keep the peace between independent nation-states (e.g. a balance of power, 'collective security', multilateral treaties, etc) will, as Kant pointed out, always be potentially unstable. Even if these arrangements are in principle able to keep the self-destruction of civilisation at bay indefinitely, governments will still have to devote a considerable fraction of their energies to being continually on guard against instabilities and taking corrective action when appropriate.

This situation has existed for the past fifty years, and, although a nuclear war has been avoided, governments have been so preoccupied with foreign policy and defence-related issues that they have had little time or energy to consider anything else. If the world view of individual politicians, and of the public at large, is dominated by a concern for military security, it will be very difficult to get a project such as the colonisation of outer space onto the political agenda.

The single most important political development that could alleviate this situation would be the implementation of a system of international law which guaranteed peace and security without the inherent risk of war. The reliability of any such system would be inversely proportional to the degree of sovereignty retained by the nation-states. A federal world government would provide the most satisfactory solution, as it would be free from present preoccupations with national security, and would be able to concentrate its energies on long-term global projects (including long-term space projects).

Resource Allocation: Turning Swords into Spaceships

The development of a space-based infrastructure will require a large-scale investment of intellectual, material and financial resources, and international cooperation will certainly be required in order to achieve an acceptable sharing of the burden [9]. However, international cooperation will not, by itself, create these resources, which must still be found from within the world economy. In the shorter term, this will necessitate a diversion of resources from other areas of economic activity. Given all the other demands on the world economy, there seems only one area that could be cut back to yield sufficient resources for space development, and that is the military sector. There are at least four reasons why the military sector is the obvious source of resources for space development:

- Very considerable resources are devoted to it. In 1990, the world spent approximately a thousand billion (10^{12}) dollars on weapons [20]. The Economist [21] has estimated that in 1985 the World's gross domestic product (GDP) amounted to US$ 12.8 x 10^{12} which (adopting the average (nominal) GDP growth rates of the OECD countries [22]) implies a 1990 value of about US$ 18 x 10^{12}. Thus, the arms budget presently accounts for about 6% of the world's GDP.
- This vast expenditure is essentially unproductive. Six percent of the gross world product might be draining into a black hole for all the good it does the global economy. A transfer of these resources to space projects (which, at worst, could not be less productive) would not adversely affect global society.
- Many aerospace companies producing high-technology weapons would be the very companies needed to develop a space infrastructure. A switch from one to the other would have only a minor impact on the industry, and on the local economies it sustains.
- Many of the world's scientific and

technical personnel are presently tied up in military research and development. By its very nature, the development of a space infrastructure will be a high-technology enterprise, which will require a large number of highly trained people. As in the case of material resources, there is probably no other sector of the world economy from which they could be taken without adverse social and economic consequences.

These arguments imply that, if the world is to afford an ambitious programme of space development, it will have to disarm. However, the degree to which disarmament will be politically acceptable will depend on the ability of international institutions to guarantee peace and security. There are doubtless a number of possible half measures, but the most secure international framework, and thus the greatest possibilities for disarmament, would be provided by the inauguration of an era of world government.

Moral Justification

That there is potentially a moral dilemma cannot be doubted. Our society is faced with a large number of other problems, and many will question the diversion of resources into outer space when so much still remains to be done on Earth. There is a school of thought in the space community which holds that space development cannot wait until all Earth's social problems have been solved. However, this argument not only turns a blind eye to substantive moral issues, but ignores the *political* point that governments will not win support by pursuing a policy which neglects problems which the majority of people consider more important than the development of outer space.

There do exist both short and long term economic justifications for space development (to be discussed in Part 2) which are not without moral implications, but these are unlikely to win this particular argument alone. It will therefore be both politically and morally necessary to ensure that space development proceeds simultaneously with efforts to improve the human condition on Earth. Further, I suggest that the resources for both sets of programmes will, in large measure, have to come from what is now the military sector of the world economy. If these arguments are accepted, there are at least two reasons why they imply the need for a world government. Firstly, governments will not disarm until the anarchic situation between nation-states is replaced by one of international law and order. Secondly, many of the social problems which need to be addressed are global problems, in need of global solutions; if they are to be tackled seriously it will be necessary to organise remedial measures on a world-wide scale, and to remove the political obstacles to their solution which arise from present assumptions of national sovereignty. Both conditions would be satisfied best within the institutional framework of a federal world government.

Conclusion

We have argued that world government is a prerequisite to solar system colonisation, and thus to interstellar travel, because it offers the surest way of satisfying the political conditions that must be met before human society will be ready for such an undertaking. These arguments largely revolve around the provision of resources for space infrastructure, and we have argued that, given a stable geopolitical environment, these could be provided by a transfer of resources from what is at present the military sector of the world economy. However, a world government will also need to draw on savings made in this sector in order to finance much needed improvements on Earth itself. Given these competing claims, it is necessary to consider why a world government should divert any resources to a world space programme. We will discuss this aspect of the problem in Part 2 in a forthcoming issue.

(In Part 2 of this article Dr I.A. Crawford will discuss the subject of 'A World Space Programme')

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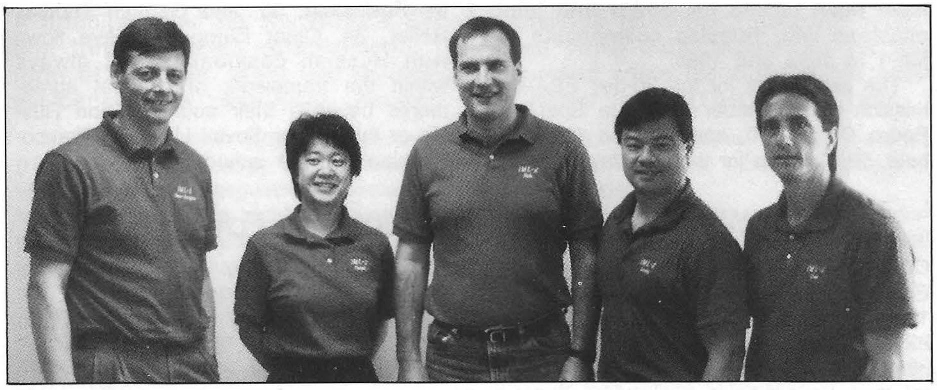
STS-65 Astronauts at Vancouver, Canada



IML-2 astronauts photographed at Shaughnessy Hospital in Vancouver (left to right) Jean Jacques Favier, Dr Chiaki Mukai, Rick Hieb, Leroy Chiao and Donald James. *Christopher Gainor*

Back Pain To Be Probed in Flight

Astronauts are not immune to that scourge of earthbound humans, back pain. Indeed a survey of 58 astronauts who have flown aboard the US Space Shuttle shows that 68 per cent of them suffered back pain in the early days of their flights. It is one of the space-related health problems that must be investigated before humans can embark on lengthy flights to Mars and beyond.

BY CHRISTOPHER GAINOR
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Back pain in astronauts is probably related to the fact that the height of astronauts increases in the microgravity environment of space and is likely to be due to expansion of the discs between the vertebrae in the spine. A study by researchers at the University of British Columbia (UBC) in Vancouver, Canada is aimed at finding the causes of back pain in astronauts. The UBC study may also shed light on symptoms suffered by earthbound patients in traction following back surgery and persons suffering from chronic back pain.

The work of the UBC researchers began on the January 1992 mission of the International Microgravity Laboratory - 1 (IML-1) aboard the shuttle Discovery. On that flight, three IML-1 astronauts were involved in back experiments and recorded height increases between 48 and 74 mm by the second day of the flight, confirming reports of similar height increases recorded during Skylab and Apollo-Soyuz flights in the 1970s. Two of the three IML-1 astronauts reported back pain. The UBC researchers are now preparing the crew of IML-2 for further studies of back growth and pain during their flight, which is scheduled for launch in July 1994.

A glimpse into the back pain problem was provided at a press conference at Shaughnessy Hospital in Vancouver attended by the UBC researchers and five astronauts who are in training for IML-2, including payload commander and veteran astronaut Rick Hieb.

Hieb said he experienced back pain and troubled sleep on his first flight, STS-39 in 1991, but not on his second flight STS-49, this being the 1992 Endeavour maiden flight in which he and two other astronauts walked in space to rescue the Intelsat VI F6 satellite. One possible reason is that the first day of his first flight was much busier and stressful than the first day of his second flight. "I was very focused on doing everything perfectly and I was very tense", Hieb said about his first flight aboard Discovery, a US Department of Defense mission in which Hieb operated the Infrared Background Signature Satellite both on the remote manipulator arm and as a free-flying satellite. On both his flights, the crews took informal height measurements during flight and 90 minutes after landing, when the height increase of space had disappeared.

Hieb said he enjoyed the compression on his back caused by the restraint straps from an exercise treadmill carried on the shuttle, and by the spacesuits used for extra-vehicular activity. The EVA spacesuits are sized an extra 25 mm to allow for growth in space, but Hieb said this is probably too little. The compression caused by the suite made it easy for him to sleep in the suit while he waited in the airlock to go outside the shuttle.

Dr John Ledsome, a professor of physiology who is principal investigator for the IML-2 back experiments, said few Russian cosmonauts have reported back pain and this could be due to either the secrecy or the fact that the cosmonauts wear compression suits regularly during their flights. Even on Earth, most people experience variation in height and are up to 10 mm taller when they get out of bed than later in the day. Summing up the IML-1 study, he said, "We were able to confirm that astronauts suffer back pain in space and we were able to record growth in height among three astronauts."

The changes seen in astronauts' backs are similar to those seen in patients whose spinal cords are stretched when they are put in traction following surgery. Many of the symptoms seen in these patients - including muscle weakness, more vigorous reflexes, back or leg pain, weakness when standing in gravity, difficulty in emptying the bladder, and bowel symptoms - are seen in astronauts in the microgravity environment of space. "The only place for growth in the spine is the discs which lie between the vertebrae", Ledsome explained, "and the increase in height could stretch the nerves that pass through the spine. This extension of the spine could put pressure on the ligaments and press on the nerves, causing pain".

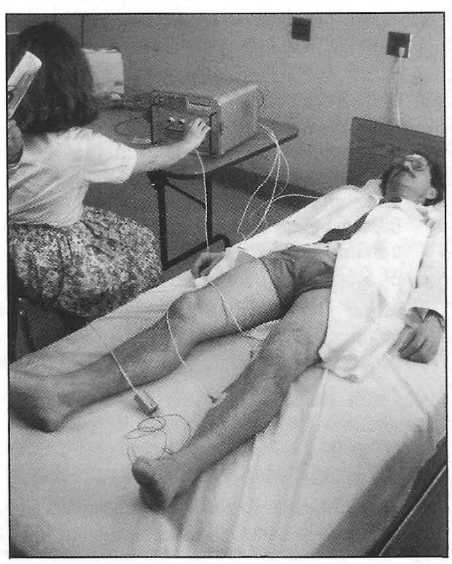
During the IML-2 flight, height will be measured and pain documented among the crew and stereophotography will be used to document changes in spinal contour and range of back motion. In addition, changes in the size of the discs between the spinal vertebrae will be measured by ultrasound. Crew members will be examined and measured before and after the flight, including magnetic resonance imaging of the discs.

Functional measurements will be taken before, during and after the flight, through electrical stimulation of the sensory nerve at the ankle. The time needed for impulses to reach the knee and the cerebral cortex will be recorded to determine functional changes in functions in the sensory pathways. As well, blood pressure response to isometric exercises, heart arrhythmia during controlled breathing and ultrasound measurements of bladder before and after urination will be recorded during the flight.

"We hope to find that stretching of the spine is not causing any disfunction of the nerves. The findings will be of importance for the longer space missions planned in the future", Ledsome said, "and could shed light on the mechanisms of chronic back pain on Earth."

Dr Peter Wing, a professor of orthopaedics at UBC who was a principal investigator on IML-1 and is on Ledsome's team for IML-2, said the work on IML-2 will add to the knowledge of spinal cord biomechanics as the back is moved in different ways in microgravity than on Earth.

Dr Peter Wing attached to electrodes to record the speed an impulse from his ankle takes to reach his brain. This is one of the experiments on IML-2. *Christopher Gainor*



Launch Report

V56: ASTRA 1C in Orbit

The first 42L Ariane launcher, equipped with two liquid strap-on boosters, lifted off from the Space Center in Kourou, French Guiana at 00:56:32 GMT on 12 May. Successfully placed into orbit was ASTRA 1C, the third direct broadcast TV satellite, as well as the French amateur radio mini-satellite ARSENE.

ESA Astronauts for Russian Missions

Two Germans, a Spaniard and a Swede have been picked for ESA's first joint missions with Russian cosmonauts to Mir-1 in 1994 and 1995.

The candidates for the 30-day ESA-Mir mission in September 1994 are Spaniard Pedro Duque, 30, and German Ulf Merbold, 52. Chosen for the 135-day ESA-Mir mission in August 1995 are Swede Christer Fuslesang, 36, and German Thomas Reiter, 34. Other Europeans have flown with Russian cosmonauts but always within the framework of bilateral agreements between their countries and Russia or the former Soviet Union. A Franco-Russian flight is scheduled for July.

STS-55: Weather Diverts Landing to Edwards AFB

Columbia landed without incident at Edwards Air Force Base, California at 10:29 am EDT on 6 May following a 9 day 22 hour flight with the German Spacelab D2 as payload. After a series of launch pad problems (May issue, p.158), STS-55 was successfully launched at 10:50 am EDT on 26 April.

STS Launches Scheduled for 1993 *(See also February issue, p.64)*

Mission	Launch Target Date	Orbiter Vehicle	Crew; (Orbital Inclination)
STS-57	June 3	Endeavour	Grabe, CDR; Duffy, PLT; Sherlock, Voss, Wisoff, MSs; (28.5°)
STS-51	mid-July	Discovery	Culbertson, CDR; Readdy, PLT; Bursch, Newman, Walz, MSs; (28.5°)
STS-58	August 25	Columbia	Blaha, CDR; Searfoss, PLT; Seddon, PL-CDR; Lucid, McArthur, Wolf, MSs; Fettman, PS; (39°)
STS-60	November 10	Discovery	Bolden, CDR; Reightler, PLT; Chang-Diaz, Davis, Sega, Russian MSs; (57°)
STS-61	December 2	Endeavour	Covey, CDR; Bowersox, PLT; Musgrave, PL-CDR; Akers, Hoffman, Thornton, Nicollier, MSs; (28.5°)

NASA/JSC and R.M.H. Baas

SATELLITE DIGEST-253

Satellite Digest is our regular listing of world space launches. It is based upon a more detailed monthly satellite listing published by the Molnlya Space Consultancy prepared by Phillip S. Clark.

Spacecraft	Int'l Desig.	Launch	Launch Site	Vehicle	Mass kg	Orbital Epoch	Inclin. deg	Period min	Perigee km	Apogee km	Notes
Raduga 29	1993-013A	Mar 25.10	Tyuratam	Proton-4	2,000 ?	Mar 25.01	1.42	1,454.13	35,981	36,297	[1]
Start-1 1	1993-014A	Mar 25.55	Plesetsk	Start-1	260	Mar 26.60	75.76	101.44	684	970	[2]
UHF 1	1993-015A	Mar 25.90	ER	Atlas 1	2,000 ?	Mar 29.07	27.76	200.78	215	9,746	[3]
Cosmos 2237	1993-016A	Mar 26.10	Tyuratam	Zenit-2	9,000 ?	Mar 26.66	71.02	101.95	849	853	[4]
Navstar 19	1993-017A	Mar 30.13	ER	Delta-2	1,881	Mar 31.98	34.86	357.68	186	20,440	[5]
SEDS	1993-017B					No Orbital Data Issued					[6]
Cosmos 2238	1993-018A	Mar 30.50	Tyuratam	Tsyklon-2	3,000 ?	Mar 31.97	65.03	92.78	404	418	[7]
Progress-M 17	1993-019A	Mar 31.15	Tyuratam	Soyuz	7,250 ?	Apr 1.58	51.62	90.16	255	310	[8]

NOTES

[1] Communications satellite, primarily for government and military applications. Satellite still in its drift orbit as this Table is being compiled.

[2] First orbital launch of booster derived from SS-20/SS-25 missiles. Satellite is a test payload prior to launches of small communications satellites. Start-1 is the first former Soviet Union booster to use solid propellants.

[3] UHF 1 (also known as UFO - "UHF Follow-On") is the first satellite to be launched in the programme to replace the Fltsatcom payloads. After launch the launch vehicle's first stage booster engines performed less than nominally, resulting in early shutdown of the sustainer engine: although the Centaur second stage burned to depletion it could not reach the planned transfer orbit for the satellite.

[4] Payload is believed to be an ELINT satellite: the orbit is coplanar with Cosmos 1980, launched in 1988. Within two days of launch the Zenit second stage disintegrated in orbit - the second such disintegration in two flights.

[5] Tenth flight of a Block 2A Navstar satellite, also designated USA 90. Satellite still in its transfer orbit as this listing is being compiled. Mass quoted above includes propellant: dry mass is 930 kg. Orbit is co-planar with that of Navstar 13.

[6] SEDS (Small Expendable Deployer System) is an experiment attached to the second stage of the Delta launch vehicle. Package deployed by tether to a distance of 20 km from rocket stage, at which time the tether was cut and the package quickly decayed in the atmosphere.

[7] First launch of an ELINT Ocean Reconnaissance Satellite (EORSAT) since January 1991, and comes within a month of the Cosmos 2122 being retired.

[8] Cargo freighter, carrying 2,603 kg of supplies to the cosmonauts aboard the Mir Complex. Docking scheduled for 1993 Apr 2.

ADDITIONS AND UPDATES

1967-043B Hitchhiker 14/OPS 1967 decayed 1993 Mar 14.

1979-067A Cosmos 1116 decayed from orbit 1993 Mar 11.

1982-023A Molniya-3 18 decayed from orbit 1992 Jun 23.

1991-005A Cosmos 2122 was manoeuvred off-station on 1993 Mar 4 and decayed from orbit 1993 Mar 28.

1993-004A Cosmos 2231 was recovered approximately 1993 Mar 25.7.

1993-010C Add the following orbital data for Cosmos 2236:1993 Mar 10.21, 64.84°, 675.75 minutes, 19,096 km, 19,165 km.

1993-012A Progress-M 16 undocked from the Mir Complex 1993 Mar 26.28 (06.50 GMT) and was de-orbited the following day.

UK Space Report

BNSC has New Director General

Derek Davis, formerly Head of the Oil and Gas Division of the Department of Trade and Industry has replaced Arthur Pryor as Director General of the British National Space Centre.

Born in Birmingham, Derek Davis was educated at Clifton and Balliol College Oxford, where he studied classics and acquired a working knowledge of French and Russian. He spent a year in India as a teacher, and has travelled widely in Europe and the Middle East. "I am delighted to be joining BNSC at a time when Britain's space aspirations, especially in Earth Observation, are meeting with success", said Mr Davis on taking up his post. "I aim to help BNSC enhance that success, bringing together space technology and data users and providers, and putting British space expertise to the best, most cost-efficient use".

'Critical Element' to be Studied

LOGICA, London is leading a consortium of 18 companies from 8 countries in a £3 million programme to study the design of the ENVISAT ground segment. ENVISAT will carry Earth observation instruments on-board the Polar Platform spacecraft and also comprises the ground segment which will acquire, process and distribute the resulting data. The ground segment is the 'critical element' in deriving benefits from the Polar Platform. The special polar orbit of the spacecraft allows it to view most of the surface of the Earth. During each orbit the ENVISAT instruments will view a different part of the Earth, moving into and out of communication with data relay satellites and ground stations throughout the world. The ground segment maintains communication with the spacecraft, processes its raw data and distributes the resulting information to users in a way which hides its complexity. An indication of this complexity is given by the immense volume of data to be handled by the ground segment, enough to fill 36,000 compact discs per year.

New Hopes for UK Spaceplane Studies

Minister Gives Support to HOTOL

At the press conference in Bristol on 21 March the UK Space Minister, Mr Edward Leigh, gave some encouragement to the HOTOL project. He said, "I personally find it an extremely exciting project. I very much hope that British Aerospace can keep their HOTOL team together".

Referring to the Government's 1987 Space Policy review, the Minister said, "We were under a lot of criticism then, particularly from the French, who decided to go into manned space flight. Hermes is still not a success and I think we took the right decision. Now that was politically very controversial back in 1987/88. We were told that we were not sufficiently committed to space and all the rest of it. In fact, I think by concentrating on Earth Observation, admittedly with a much smaller budget than France (I think France spends eight times more than we do), we have concentrated our resources and we have got more out of it".

Mr Leigh went on to point out one slight improvement for the future. The Ministers' meeting in Grenada last year approved an ESA study programme (FESTIP) to look at post Ariane 5 launch vehicles, and the UK is hoping to subscribe to a small part of this. He said "What is going to happen after the present launchers, we do not know. I would say personally it would be exciting if we could get HOTOL up and running. But I cannot say if we will get back in a big way into launchers".

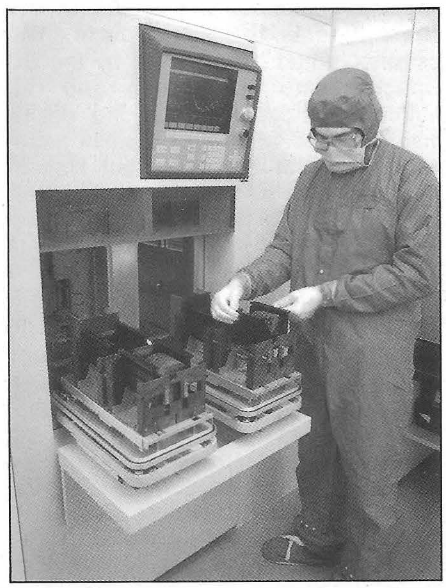
Subsequent to the press conference, events have moved forward with indications from official quarters that a draft programme is being considered involving an expenditure of £1 million per year over the next three years. The objective will be to investigate various configurations and conduct various technical studies, particularly relating to materials and their properties.

A decision on the study programme is expected shortly and if this is favourable the UK can expect to secure important contracts from ESA for work on interim HOTOL, Skylon and other technologies.

ESA Approval for UK Space Components Facility

GEC PLESSEY SEMICONDUCTORS (GPS) now has ESA Capability Approval for its 2.5 micron Silicon-On-Sapphire (SOS) range of products. GPS expects shortly to gain ESA Approvals for its 1.5 micron products and for its Thin and Thick film Hybrid capability. No other European manufacturer can offer such a range of radiation hard components.

"As a result of upgrading the facility to obtain the Approvals", explained Ray Gleason, GPS' Marketing Director, "we can now provide Space Class finishing and assembly for a whole range of products made using our other technologies. "We have built close partnerships with the major satellite builders to the extent that we have a number of development contracts to produce custom components. Because of the long lead times in designing and assembling satellites, we have an on-going programme to ensure that customers are kept up to date on all the latest developments in our products. Should problems occur, as they often do with such complex items as satellites, we have a wealth of expertise to draw upon to find the solutions. As a result, our products are now being designed into most of the next generation of satellites".



An operator loads Silicon-On-Sapphire (SOS) wafers into an automated polysilicon etching system at GEC Plessey Semiconductors' facility at Lincoln. Silicon-On-Sapphire is inherently the best technology available for the manufacture of integrated circuits destined for applications with severe environmental conditions, notably space.

The US Astronaut Hall of Fame/Space Camp Florida facility located on State Road 405, just off US 1, at the entrance to the Kennedy Space Center. The entire facility, dedicated in 1990, is a joint venture between the Mercury Seven Foundation and the US Space Camp Foundation, both non-profit, tax-exempt organisations. The Space Shuttle is a full-scale replica (called "Shuttle to Tomorrow") opened to the public in May 1992. Inside the cargo bay is a 72-seat theatre. *Photos supplied by the author*

Gemini

On Saturday 20 March, 1993, old times were relived at the Space Coast in Florida, USA. That morning, America's early space pioneers from projects Mercury and Gemini rode in a parade through Cocoa Beach in vintage Corvettes from the 1950s and 1960s and American flags were passed out along the route. At a news conference later that day the tone was however one of pessimism as the astronauts commented on the present day lack of commitment and vision surrounding the future of space.

Leading the parade were about 65 students from the Florida Air Academy in Melbourne, who were divided into a colour guard, drum and bugle corps, drill teams and honour guard. The motorcade re-enacted the earliest parades when America first launched astronauts into space and it stirred emotions among the onlookers comparable with the feelings people first felt back in the early sixties.

Of the 19 astronauts who flew on Mercury and Gemini missions [1] from 1961 to 1966, 16 were present. Most of them moved on to the Apollo Moon landing programme. Therefore the group included six moonwalkers and five others who had orbited the Moon. Also expected was the former grounded Mercury astronaut Donald K. Slayton. Missing was Dave Scott, who had to cancel at the last minute. Also absent were Gus Grissom and Ed White, who died in the January 1967 Apollo-204 spacecraft fire. Grissom's widow Betty and White's son Edward III attended.

It was a sort of rarity to have all of America's pioneer astronauts at the same time in the same place. The astronauts had been invited by the US Space Camp Foundation and the Mercury 7 Foundation for the official installation of 13 Project Gemini astronauts into the US Astronaut Hall of Fame, located in Titusville at the gateway to the Kennedy Space Center. More than 500 people bought tickets for that ceremony.

Sixteen astronauts (among them the three Mercury veterans Grissom, Cooper and Schirra) flew ten missions in the two-person Gemini-capsules boosted to low Earth orbit on Titan 2 rockets. Project Gemini, America's second man-in-space programme, was the bridge between America's first tentative forays into space in Mercury and the Apollo moonflights. The programme perfected all of the flight techniques necessary to go to the Moon including rendezvous, docking, space-walking and long-duration flight. There were 12 flights, including two unmanned tests.

The Gemini astronauts during the news conference in the Hall of Fame, March 20, 1993. *Above*: Young, McDivitt, Conrad, Borman. *Below*: Lovell, Stafford, Cernan, Collins, Gordon, and Aldrin. Except for McDivitt they all travelled to the Moon, four of them (Young, Conrad, Cernan and Aldrin) walked on it.

The Gemini astronauts joined the original seven Mercury astronauts, who were enshrined in the Hall of Fame when it opened in 1990. The Gemini induction was the first since that time. In the Hall each astronaut is featured in his own special section with personal space mementoes on display. Video films and photographs depict their flights. To accommodate the exhibits for the additional Gemini astronauts the attraction underwent a $300,000 face lift, provided by a grant from the Brevard County Tourist Development Council and a contribution from the Coca Cola Company.

Preceding the induction ceremony the Gemini astronauts held a news conference at 3 pm (March 20, 1993) in the Hall of Fame. Gemini-B astronaut Neil Armstrong, who was the first human to walk on the Moon, was not present at this conference, but arrived for the induction itself at 4:30 pm.

Astronauts Honoured

BY ANNE VAN DEN BERG FBIS
The Netherlands

The tone of the conference was one of pessimism. The astronauts commented that space stands at a crossroads now and that there is no real commitment or vision any more. They hoped to encourage younger people into pursuing and supporting space and hoped the public would come away from the Hall of Fame with a sense of what times were like when ten Gemini missions were flown in twenty months during 1965 and 1966.

Christopher C. Kraft Jr., flight director during the Mercury and Gemini programmes and later director of NASA's Johnson Space Center served as host for the induction ceremony. One by one, in the order that they flew, Kraft called out the names of the new inductees. And one by one, as brief video's of their flights flashed on a large screen, the former astronauts stepped forward to accept plaques symbolising their entrance into the Hall of Fame. Edward H. White III accepted for his father.

Reference

1. In the order that they flew: Alan B. Shepard Jr., Virgil I. Grissom, John H. Glenn Jr., Malcolm S. Carpenter, Walter M. Schirra Jr., L. Gordon Cooper Jr., John W. Young, James A. McDivitt, Edward H. White II, Charles Conrad Jr., Frank Borman, James A. Lovell Jr., Thomas P. Stafford, Neil A. Armstrong, David R. Scott, Eugene A. Cernan, Michael Collins, Richard F. Gordon Jr., and Edwin E. Aldrin Jr.

Gemini Hall of Fame Inductees

John W. Young holds the record for the most space flights, six. He flew two Gemini flights, Gemini 3, which was the first, and Gemini 10, which he commanded. He orbited the Moon on Apollo 10, walked on the Moon on Apollo 16, and commanded two Space Shuttle missions, STS-1, which was the first, and STS-9.

James A. McDivitt commanded both the Gemini 4 first space walk mission and the Apollo 9 flight in which the Lunar Module was tested for the first time in Earth orbit.

Edward H. White II became America's first space walker on the Gemini 4 mission. He later died tragically with Gus Grissom and Roger Chaffee in the 1967 Apollo 1 launch pad fire.

Charles Conrad Jr piloted Gemini 5, commanded Gemini 11, walked on the Moon on Apollo 12 and commanded the Skylab 2 space station mission.

Frank Borman commanded Gemini 7, the first space rendezvous mission, and commanded Apollo 8, the first flight to orbit the Moon.

James A. Lovell piloted Gemini 7, which was part of the first space rendezvous, orbited the Moon on Apollo 8 and commanded the aborted Apollo 13 Moon flight.

Thomas P. Stafford flew on Gemini 6, the first space rendezvous mission, commanded Gemini 9, orbited the Moon on Apollo 10, and commanded the American Apollo craft that linked in orbit with a Soviet Soyuz craft in 1975.

Neil A. Armstrong commanded the Gemini 8 mission which conducted the first space docking before making an emergency landing because of a control problem and was the first human to walk on the Moon on Apollo 11.

David R. Scott flew on Gemini 8 with Armstrong, was command pilot on Apollo 9 and walked on and drove the first Lunar Rover on the Moon as commander of Apollo 15.

Eugene A. Cernan walked in space on Gemini 9, orbited the Moon on Apollo 10 and walked on the Moon as commander of Apollo 17, the last Moon mission. He was the last man on the Moon.

Michael Collins walked in space on Gemini 10 and circled the Moon as Apollo 11 Command Module pilot while America's first moonwalkers, Neil Armstrong and Buzz Aldrin, explored the surface.

Richard F. Gordon Jr walked in space on Gemini 11 and orbited the Moon on Apollo 12.

Edwin E. Aldrin Jr walked in space on Gemini 12 and explored the Moon on the Apollo 11 mission.

ESA Simulates Crewing of Space Station

For 60 days, from 7 September to 6 November 1992, a crew of one woman and three men lived and worked shut inside a completely isolated pressurised chamber/laboratory (the TITAN hyperbaric complex at the DLR Aeronautical Medicine Institute near Cologne, Germany) preforming experiments designed to evaluate the impact of isolation and confinement on human physiology and psychology, together with space-related operational and technological experiments.

This was not the first time that ESA has been involved in an experimental campaign to study living in long-term isolation and confinement. A crew of six male "EMSInauts" (EMSI: European Manned Space Infrastructure) was isolated from 17 September to 15 October 1990 in the hyperbaric chambers at the Norwegian Underwater Technology Centre (NUTEC). During this isolation experiment called ISEMSI (Isolation Study for the European Manned Space Infrastructure), the crew carried out experiments regarding psychology, physiology and space-related operations.

Objectives and Experiments

The 1992 campaign, called EXEMSI '92 campaign (Experimental campaign for the European Manned Space Infrastructure) had similar objectives, the simulation basically re-creating a long duration mission on a space station with a mixed crew composed of young European scientists selected by ESA: Anita Vestin (Sweden), Clemens Lothaller (Austria), Hildo Krop (the Netherlands) and Matthieu Roulet (France). Before entering the chamber, the crew had gone through two months of training on the different experiments to be performed during the mission. The Astronauts Support and the Astronauts Training Divisions of ESA's EAC (European Astronauts Centre) in Cologne were responsible for the selection and training of the crew according to standards similar to those required for choosing and preparing astronauts for space missions.

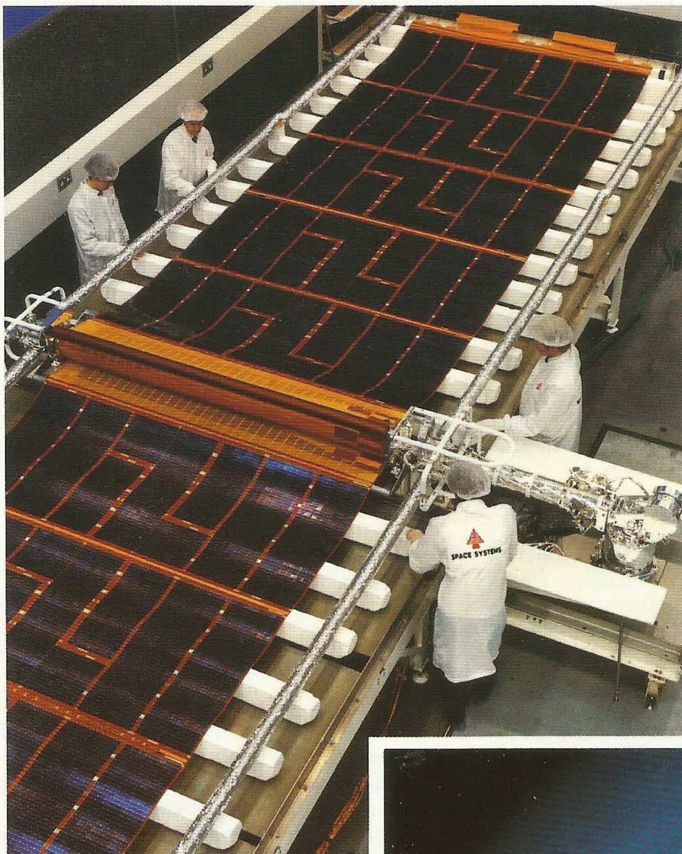
The Chamber Crew of four was assisted by a Ground Crew composed of five persons (three women and two men), including the two back-ups for the Chamber Crew. The Ground Crew was constantly in touch with the Chamber Crew via videocameras, audio links, telephone and telefax, while the Chamber Crew had only audio links to the Ground Crew.

The EXEMSI '92 project was carried out within the framework of ESA's Long Term Programme Office in the Directorate of Space Station and Microgravity. The project was supported by the Columbus System and Projects Department of ESA's ESTEC (European Space Research and Technology Center), Noordwijk, the Netherlands. DLR, the German research establishment for aerospace, was entrusted with the technical management of the test facility and the medical and safety responsibility for the crew.

The 30 scientific experiments which were carried out in the 2 months campaign were processed by the crew for scientists from Universities and Research Institutes in Denmark, France, Germany, Great Britain, Italy, the Netherlands, Norway and Russia. During the isolation period, more than 1.5 gigabytes of data have been collected and distributed to the participating scientists for further processing and analysis.

STS-61

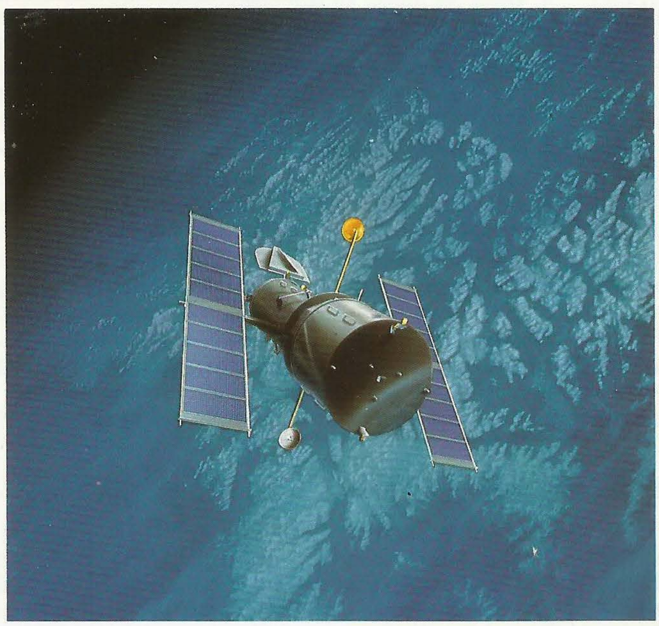
Plans to Fix Hubble



Astronauts from the STS-61 crew visited British Aerospace Space Systems at Bristol this March as part of their mission training. The flight will perform the first servicing of the Hubble Space Telescope and the astronauts were familiarising themselves with the second set of flight solar arrays. These are to be exchanged with the first arrays and as the Payload Commander, Story Musgrave, explained "We cannot train with the real hardware but here we get a chance to meet and see the real thing. We don't want to see them for the first time on orbit."

On the 10th March the astronauts took time out from their busy training session to meet the press and show off the flight set of arrays before their final function testing and delivery to NASA at the Goddard Space Flight Center in May.

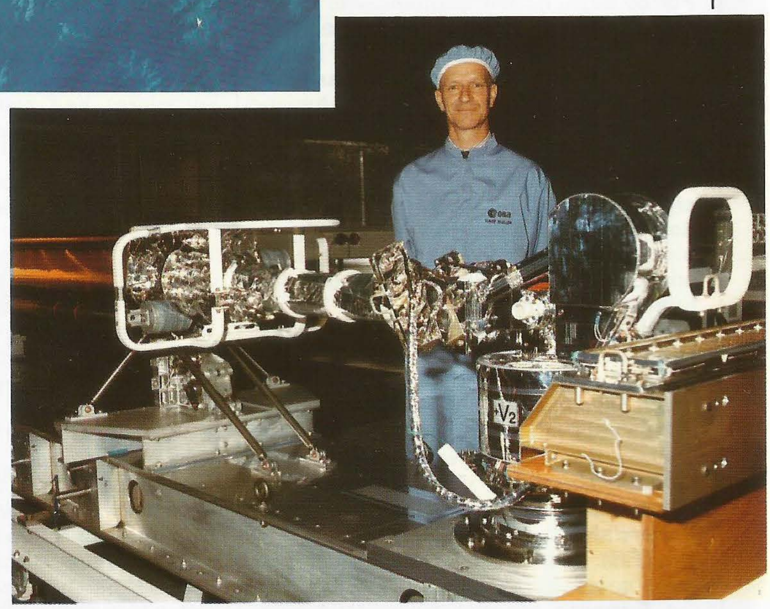
MARK HEMPSELL
University of Bristol



Above: The Solar Array at BAe Bristol under test while fully deployed on a water table. The array cannot support itself under 1 g and is supported on polysturene floats on water.

The Hubble Space Telescope is a 2.4 m Cassegrain reflecting telescope, designed to focus light at wavelengths between 115 nanometres and 10 mircometers. It is a joint ESA/NASA project to which ESA contributes the solar arrays, the Faint Object Camera and a team of European scientists. In return, a minimum of 15% of the observing time is made available to astronomers from ESA member states.

Below Right: STS-61 mission specialist Claude Nicollier, who is an ESA astronaut and BIS Fellow, inspects the array on his visit to BAe Bristol. In order to assist the astronauts' EVAs, the arrays are fitted with a white-coloured handle system, part of which can be seen in the picture.



What Is COSTAR ?

One of the most publicised problems with Hubble found after launch was the incorrect primary mirror shape leading to spherical aberration effects on the images. A part of the press conference was devoted to explaining the problem and how it is to be resolved.

Because of the high precision to which the mirror was ground it is possible to correct for this effect by computer processing of the images, but only for relatively bright objects where there is sufficient light for the correction algorithms to work. Improving Hubble's optics will enable it to see fainter objects and hence deeper into the Universe.

A good example of the current limitation is the measurement of Cepheid variable stars in distant galaxies. These stars vary their brightness in a fixed manner relating to their size. Accurate measurement of their brightness and the pattern of variation enables a precise measurement of their distance. With the current optics Hubble can only measure out to around 10-20 million light-years.

STS-61 will insert a unit called COSTAR (Corrective Optics Space Telescope Axial Replacement) into the optical chain. This essentially works like a pair of spectacles improving the performance for three of the four main instruments (the new Wide Field Planetary Camera has its own corrective optics built in and does not need COSTAR).

Astronauts at Bristol

Space Telescope Revealed

Record Five EVAs Planned
NASA has now announced that STS-61 is scheduled as an 11-day misison to accommodate a record five spacewalks with the capability for an additional two, if needed.

The Mission

STS-61 mission will be flown by a crew of seven on the Space Shuttle Endeavour. It is currently due to be launched in December this year. It will be a night launch and is planned to last eleven days.

Endeavour is being used because its performance is needed to carry the 7.2 tonnes of servicing equipment to the high altitude (600 km) at which the Hubble orbits. It also has additional nitrogen, oxygen and hydrogen tanks that provide air and power for the mission.

STS-61 will be the first American mission to service an orbiting satellite. Previous missions of this type have been repair and recovery missions to spacecraft that have gone wrong and were not planned before the spacecraft was launched. In the case of the Hubble Space Telescope, manned servicing by the Shuttle was always planned to enable it to achieve its planned fifteen-year life.

All five astronauts who will specialise in the servicing tasks were present at Bristol (the two Shuttle pilots did not require array familiarisation as part of their training). Four of them who will take part in EVAs are Story Musgrave, Jeffrey Hoffman, Kathryn Thornton and Tom Akers and all have had very extensive EVA experience on previous Shuttle flights.

The fifth mission specialist is Claude Nicollier, who is an ESA astronaut from Switzerland, and he will be responsible for the remote manipulator arm which will first be used to capture the Hubble and then to support the EVA astronauts during servicing tasks. He has also had previous experience of this task as he flew on the STS-46 in August 1992 where he used the manipulator to deploy the Eureca satellite.

The STS-61 will replace or add seven items during at least three (and possibly more) EVAs. These are:

1. Exchange solar arrays
2. Replace Wide Field Planetary Camera
3. Install COSTAR corrective optics
4. Replace GHRS Relay Box
5. Install a Coprocessor Module
6. Replace some gyro units
7. Install an additional Magnetometer.

As with any servicing task some of the jobs replace items with limited life (such as the solar arrays), some jobs replace parts that have failed (like the gyros and relay box) and some are improvements of the system (such as the new Wide Field Planetary Camera or the Coprocessor).

Array Replacement

The main focus of the press conference was the solar array replacement. The original Hubble solar arrays were made by British Aerospace under a £15 million contract to ESA. The second set for the STS-61 flight was procured under a second contract worth £11 million.

Each wing of the array contains 24,380 solar cells made by Telefunken Systemtechnik GmbH in Germany and generates about 2.5 kilowatts at the beginning of its life. When deployed the 160 kilograms wing is 12 meters long overall and 2.8 meters wide. The original design had to content with problems of atomic oxygen attack on the kapton substrate and the control of the very low structural frequencies, while making the whole thing astronaut friendly.

The original purpose of the array replacement was to keep the power available to Hubble in excess of 4.5 kW. Any photovoltic array degrades over its life in orbit due to radiation damage and to maintain power levels over Hubble's fifteen-year life it is planned to install fresh arrays during some of the servicing missions. The array that returns will be subject to extensive examination as it is rare to get a close look at hardware that has been in orbit so long. ESA project manager Dave Eaton described the set of first arrays as "a four year LDEF" (Long Duration Exposure Facility).

However the replacement allows modifications that reflect the in-flight experience and Mike Newns BAe project Manager for the Space Telescope Arrays explained these changes.

In operation the solar power arrays were found to be introducing a jitter that affected Hubble's very precise pointing. This happens as Hubble enters and leaves eclipse and is due to stick and slip in the booms and mechanisms because, as they are heated and cooled, they experience differential expansion and contraction.

NASA already operates a solution to this problem using Hubble's on-board computers to counteract the jitter effect with the control system. However this takes a lot of the computer's memory and it was decided to use the opportunity to ease this problem so far as possible. Thus by improving the array's thermal performance it is hoped to release computer memory for more productive scientific use.

British Aerospace have made three changes to the design to improve the jitter performance. The first and most obvious from the outside is the inclusion of a thermal blanket which covers the deployable bi-stem booms which support the array panel. These are manufactured from aluminium coated teflon disks which are laser welded to form the concertina form of the blanket. The packing of the shield is impressive, an extended length of almost six meters is compressed into around one tenth of a meter when stowed.

The second modification is to replace the mechanism which tensioned and supported the far end of the blanket with nine simple coil springs. The third modification is the addition of a brake on the outboard end of the drum about which the array is wrapped before deployment. This brake can be switched on and off in orbit by ground command and stops thermal movement of the drum.

In addition to the modifications to resolve the thermal jitter British Aerospace also added additional handles and a connector support brackets to help the astronauts handle the arrays during EVA.

The Future

It is rare for British space engineers to be able to work on spacecraft which involve a manned presence and British Aerospace clearly undertook its task with relish. The results are impressive and the astronauts were full of praise for the British team and the work they had put in.

However with not even a contract for a third array set in place, it looks as if it will be a long while before British engineers will have another chance to show what they can contribute to a manned space mission.

STS-61 Crew

Name	Assignment	Previous Flights
Richard O. Covey	Commander	STS-51-I, STS-26, STS-38
Kenneth D. Bowersox	Pilot	STS-50
Story Musgrave	Payload Commander	STS-6, Spacelab 2, STS-33, STS-44
Jeffrey A. Hoffman	Mission Specialist	STS-51-D, STS-35, STS-46
Kathryn C. Thornton	Mission Specialist	STS-33, STS-49
Tom Akers	Mission Specialist	STS-41, STS-49
Claude Nicollier	Mission Specialist	STS-46

Discovery in Orbit with Second ATLAS Payload

STS-56

The STS-56 flight crew enjoys breakfast in the Operations and Checkout Building before departing to Launch Pad 39B and a second launch attempt of the Space Shuttle Discovery. From the left are Mission Specialists Kenneth D. Cockrell and Michael Foale; Commander Kenneth D. Cameron; Mission Specialist Ellen Ochoa; and Pilot Stephen S. Oswald. *NASA*

Atmosphere and Sun Observed as Crew Link-Up with Schools

Discovery was launched on the STS-56 mission early on the morning of April 8, 1993 from the Kennedy Space Center in Florida. The launch, the sixteenth launch for Discovery and the fifty-fourth for the Space Shuttle program, followed an on-pad abort of Discovery two days earlier and an on-pad abort of the Shuttle Columbia on March 22.

BY ROELOF SCHUILING
at the Kennedy Space Center

Installation of Experiments

Discovery had landed at KSC on 18 December 1992 after completing the STS-53 mission. The Shuttle schedule at that time had the STS-56 launch for late March 1993 following the planned February 25 launch of the Shuttle Columbia on the STS-55 mission.

The primary payload for the STS-56 mission was the ATLAS-2 Atmospheric Laboratory for Applications and Science. The ATLAS instruments record the Sun's energy output and measure the chemical composition of the middle atmosphere with special emphasis on the levels of ozone. The first ATLAS mission was launched on 24 March 1992 on the Atlantis Space Shuttle. Seven of the ATLAS-1 instruments were also aboard ATLAS-2, six of the instruments being mounted on a Spacelab pallet in Discovery's payload bay while the seventh instrument was mounted in two Get Away Special canisters on the payload bay wall.

Discovery also carried the SPARTAN-201 deployable satellite. SPARTAN is a free-flying instrument platform that is extended away from the orbiter by the remote manipulator arm and is then released. Once released, the SPARTAN drifts free and conducts observations. It is retrieved later in the mission by the Shuttle and returned to Earth. Multiple missions with the SPARTAN system are planned and SPARTAN payloads were aboard STS-51G and STS-51L. SPARTAN-201 carried the Ultraviolet Coronal Spectrometer and White Light Coronagraph Instruments.

Six of the twelve ATLAS-1 instruments were removed from their pallets in the KSC Operations and Checkout building, following the STS-45 flight, and sent back to their principal investigators for checkout and calibration for use on STS-56. These instruments were mounted on the pallet during the summer of 1992. Integration and systems tests followed and SPARTAN-201 joined ATLAS-2 in the Operations and Checkout building in early February of 1993. On February 8, 1993 the ATLAS-2 and SPARTAN-201 payloads were moved to the Orbiter Processing Facility for installation in Discovery's payload bay.

Launch Delay

By this point in Discovery's STS-56 preparations its planned launch date had slipped to the end of March-early April. The slip was caused by the change in Columbia's STS-55 launch date, this being due to the need to replace hydrogen turbopumps on Columbia's engines in order to verify that the proper seals were installed.

In addition to the delay due to STS-55's schedule, STS-56 had also been impacted by the need to check the turbopumps on Discovery's engines. The most effective way to do this, as Discovery had not yet been mated to its external tank-solid booster combination and rolled out to the launch pad, was to remove Discovery's engines while it was in the OPF and to install three new engines while Discovery was in the Vehicle Assembly Building (VAB). This approach had minimal impact on schedules and allowed the STS-56 Shuttle preparations to follow the planned timeline as closely as possible. Accordingly, the engines originally installed in Discovery in early February were removed in late February and Discovery moved to the VAB on the night of March 2-3.

The new main engines were installed in Discovery beginning on March 8 and preparations were made to move the Space Shuttle to Launch Complex 39B on the 13th. The rollout to the pad was delayed, however, due to weather as a strong cold front moved through the area. The rollout began at 7:28 on the morning of March 15 and the Shuttle was "hard down" on the launch pad by 2:28 that afternoon. The STS-56 flight crew arrived at KSC for their required pad safety training for the two day countdown simulation. The practice countdown was completed on March 18.

At this point STS-55, Columbia's Spacelab mission, was set for launch on March 22. However, the launch was aborted after the engine start sequence began when a check valve failed to function correctly. Due to the time required to analyse the check valve problem and to refurbish the Columbia for a second launch attempt, Discovery was now the next scheduled Shuttle to attempt launch. Since Discovery had the same check valves as Columbia, leak checks were made during March 27-28 to determine if Discovery's valves might also have a problem. These checks led to the replacement of one of the check valves on Discovery's main engine number one.

On March 30, Shuttle managers confirmed the planned April 6 date as the official launch date with T-0 at 1:32 am. On Saturday April 3, the STS-56 launch countdown began at 5:00 am. 24 hours and 32 minutes of built-in-holds would take the count to 1:32 am on the morning of April 6. After picking up the countdown, launch crews checked out navigation aids and checked inertial measurement

units. Operations began to prepare the main propulsion system and the main engines for cryogenic loading later in the count. The crews conducted stowage in the flight deck and middeck areas, and performed microbial sampling of the orbiters drinking water supplies. The first built-in-hold occurred at T-27 hours in preparation for loading the fuel cell hydrogen and oxygen reactants.

After the 4 hour hold the count was resumed early Sunday April 4 at T-27 when fuel cell cryogenic reactants' loading began. After completion of the loading, which is a hazardous procedure requiring nonessential personnel to leave the pad, the pad was reopened for regular work. Orbiter communications, flight control and navigation systems were activated. In the crew area, the seats for mission specialists were installed. Although the pilot and commander seats remain in place on the flight deck, mission specialists seats are not installed until the countdown - and removed after the Shuttle reaches orbit - to allow access to cabin stowage locations.

On Monday April 5 the rotating service structure that provides access and weather protection to the Shuttle midbody was rotated away from the STS-56 Shuttle. Safety personnel performed inspections of the launch pad and the pad's sound suppression system tank was filled with water. Time critical flight crew equipment was installed and, following a flow-through purge, the fuel cells were activated.

The flight crew arrived at the launch pad and entered the orbiter. All countdown preparations were going smoothly and the countdown proceeded down as far as the planned built-in-hold at the T-9 minute mark. At that point the count was held beyond the planned 10 minute length to evaluate a possible sensor concern and to assess the weather at the KSC landing facility. The weather concern was with marginal winds that might be encountered in the event that an early ascent abort occurred, thus requiring a return to the launch site for landing. These issues were satisfactorily resolved, however, and the countdown was later resumed with a projected launch one hour later than initially planned.

The countdown proceeded to the T-11 seconds point, at which time the onboard computers initiated an abort. Instrumentation on the liquid hydrogen high point bleed valve in the main propulsion system was indicating off when it should have indicated on. The launch crews immediately began safing the pad and the flight crew returned to their quarters. Tests later showed that the problem had been with the instrumentation and not the valve itself. Tests of the valve confirmed that it was working correctly.

The countdown was recycled to the T-27 hour point with a new projected launch time of 1:29 am on Thursday April 8 - a 48 hour recycle.

The countdown proceeded from the T-27 hour point. On Wednesday April 7 the late stowage of time-critical items and middeck payloads was completed during the morning. At 9:30 am the countdown entered the T-11 hour built-in-hold. This hold, 13 hour and 12 minutes in the aborted original countdown, was reduced to approximately 90 minutes for the recycled countdown. The remaining built-in-holds which were set at T-6 and T-3 hours and T-20 and T-9 minutes were not reduced in length.

About the Crew

Dr Michael Foale, the Second Briton in Space Makes Return Flight

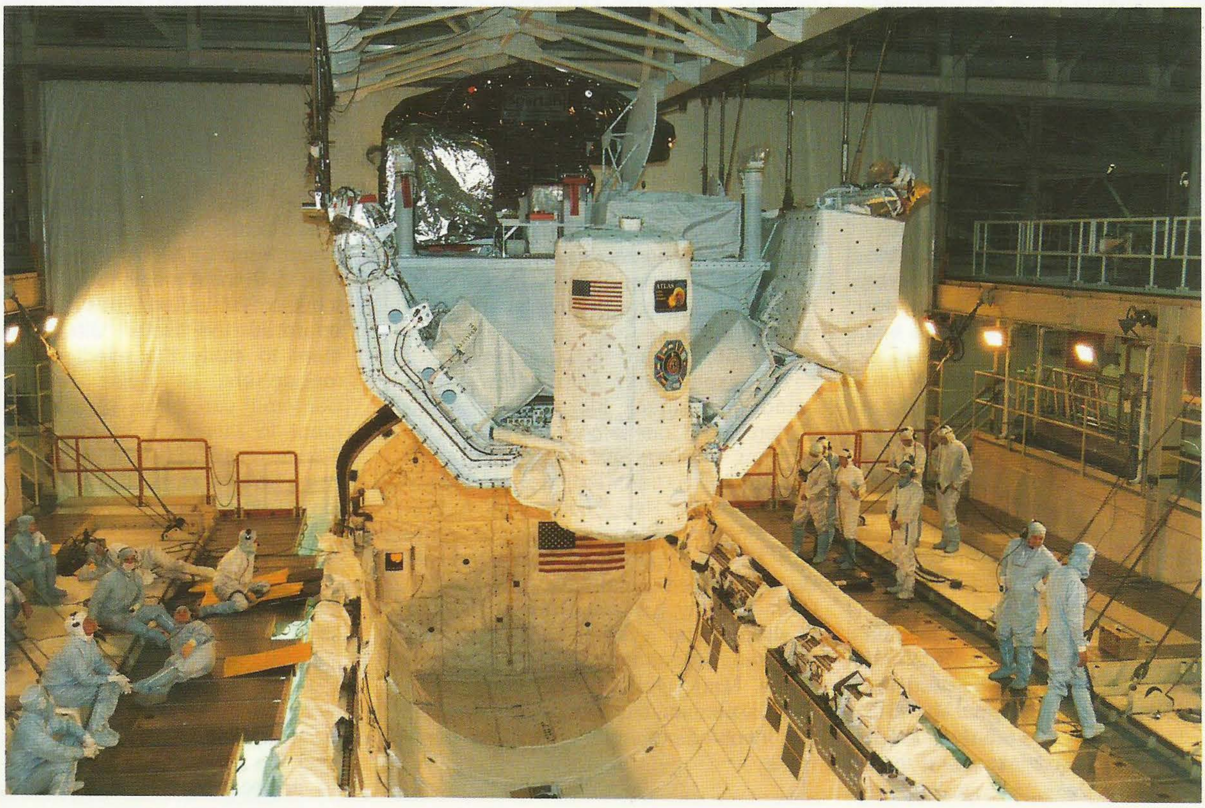
The commander of the STS-56 mission was Kenneth D. Cameron, Col., USMC, 43, who also flew as pilot on STS-37. Steven S. Oswald, 41 was the STS-56 pilot. Payload commander for the mission was C. Michael Foale, PhD, 36, who had flown as mission specialist on the STS-45 ATLAS-1 mission in March 1992. Mission specialists making their first space flights were Kenneth D. Cockrell, 42 and Ellen Ochoa, PhD, 34.

At 5:09 pm on April 7 the reloading of the external propellant tank with liquid hydrogen and liquid oxygen began. Following that three-hour operation, the inspection team was deployed to the pad to make final assessments of the Shuttle.

At 8:34 pm the flight crew were awakened and had breakfast at 9:04 pm. Following their weather briefing the crew put on their flight equipment and departed their Operations and Checkout building quarters for launch pad 39B at about 10:14 pm. Following the crew's entry into Discovery's cabin, the hatch was sealed at about midnight.

The countdown proceeded without incident and at the T-9 minute built-in-hold the Launch Director and Mission Management Team completed their final polls for launch. The crew access arm was retracted at T-7.5 minutes and at T-5 minutes the Auxiliary Power Units which provide control for the hydraulic systems

Two major payloads for the STS-56 mission aboard Discovery are lowered into the orbiter's cargo bay in Bay 3 of the Orbiter Processing Facility. Mounted on a Spacelab pallet is the primary payload, the Atmospheric Laboratory for Applications and Science-2 (ATLAS-2). The Shuttle Point Autonomous Research Tool for Astronomy (SPARTAN-201), with a protective covering over its instruments, is mounted on a platform directly behind ATLAS-2. *NASA*



were started. The orbiter transferred to internal power at T-3.5 minutes. The liquid oxygen propellant tank was pressurised at minus 2 minutes 55 seconds and the liquid hydrogen tank at minus 1 minute 57 seconds. At T-31 seconds the "go for automatic sequence" was given and at minus 6.6 seconds the main engine ignition sequence started. At 1:29 am on the morning of April 8, 1993 the STS-56 Space Shuttle mission lifted off from the Kennedy Space Center's Launch Complex 39B. Ascent phase of the mission was normal and after reaching orbit the crew prepared for the mission operations.

Flight Day One

Activation of the ATLAS-2 instruments was the crew's first main activity and was completed without problems in the early hours of the mission. Mission specialist Ochoa conducted checkout operations of the orbiter's Remote Manipulator System (RMS) to be used during the deployment of the SPARTAN-201 satellite on the morning of April 11. The crew also spent time setting up other experiments including the SAREX amateur radio equipment, the HERCULES precise location system, and the bioreactor. The bioreactor, designed to study long-term effects of weightlessness on the human immune system was found to be turning itself off intermittently due to possible overheating. Flight controllers set about developing a plan to provide cooler air flow to the experiment.

STS-56 orbital activity was conducted on a twenty-four hour per day schedule with the crew divided into two shifts. The "Red team" of Foale and Cockrell took over control of on-orbit activity at about 12:30 in the afternoon as the "Blue team" prepared to go to sleep. The Red team succeeded in dealing with the experiment overheating problem by removing the unit from its middeck locker location and taping it to the wall of the middeck cabin area. This allowed them to route a cooling air hose to the unit in order to provide additional air to the unit's cooling vent.

The Blue team of commander Ken Cameron, pilot Stephen Oswald and mission specialist Ellen Ochoa ended their sleep period at about 8:30 pm.

Flight Day Two

After beginning the Blue team's work shift, Steve Oswald performed manoeuvres to place the orbiter in a position such that the ATLAS-2 instruments could observe the first and last rays of each orbital sunrise and sunset. This put Discovery in a solar-relative rather than an Earth-relative attitude. When Discovery was on the night side of the Earth, Oswald rolled the orbiter to point the instruments toward deep space to cool them after their exposure to the direct sunlight. The Solar Backscatter Ultraviolet instrument was primarily affected.

After the completion of checks, the RMS robot arm was left in its extended park position, poised above and to the left of the orbiter's nose. The arm was left in this position throughout the flight when not in use to avoid interference with the ATLAS-2 instruments' field of view.

Cameron used the SAREX amateur radio equipment to talk to stations on the ground and reported contact with students at the Royal Grammar School in Surrey, England was well as with schools in New York and in Maryland.

The crew activated the Solar Ultraviolet Experiment (SUVE) which was designed by students at the University of Colorado. The SUVE data will be used to study how ultraviolet radiation is absorbed by the upper atmosphere and to correlate the radiation with sunspots and solar flares.

Flight Day Three

Mission commander Cameron, pilot Oswald and mission specialist Ochoa utilised the SAREX radio equipment to talk to students at the Sedbergh School in Cumbria, England and with students in Portugal and South Africa as the Shuttle's flight passed overhead.

A brief contact with the Russian Mir space station was reported using the SAREX amateur radio equipment. Mission specialist Foale reported that it had only been long enough to exchange greetings as the antenna was pointing down to facilitate contact with ground receivers, while Mir was orbiting 50 miles above the Shuttle's path.

STS-56 was the first Shuttle mission with the capability of sending images from the HERCULES experiment camera down to Mission Control during the flight, and this work continued.

Flight Day Four

The primary focus of the day's activities was the deployment of the SPARTAN satellite. The instrument platform was released from Discovery at 2:11 am. SPARTAN operated for about 48 hours while it was away from the orbiter's payload bay. Its instruments studied features such as holes and streamers in the Sun's corona and their effect on the speed and strength of the solar wind. The information gathered by SPARTAN was recorded onboard the satellite for playing back after SPARTAN returned to Earth with Discovery. SPARTAN itself had no capability to relay information to the Earth. Discovery began to separate from SPARTAN at a rate of about 8 miles per orbit after the release.

Pilot Steve Oswald spent much of his time carefully manoeuvring Discovery away from SPARTAN while keeping the ATLAS-2 instruments pointed at the Sun for their scheduled observations. Ochoa operated the Solar Ultraviolet Experiment to study the effect on the Earth's ionosphere of solar radiation. Ken Cameron used the SAREX radio equipment to talk to students at schools in Texas and Pennsylvania - including his son who is a student at a school in Houston, Texas.

Flight Day Five

Discovery began initiating manoeuvres to return to the SPARTAN satellite in preparation for satellite retrieval on Flight Day Six. The orbiter performed a series of three manoeuvring engine burns early in the day. The first two were to align Discovery and the third was to drop the orbiter to a lower orbit to begin its approach toward SPARTAN at its

Experiments Onboard

Three of the ATLAS-2 instruments were designed to conduct atmospheric chemistry research. The Atmospheric Trace Molecule Spectroscopy (ATMOS) measured chemical and physical composition of the atmosphere and concentration of chemical compounds from 10 to 140 km above the Earth's surface. The Millimeter Wave Atmospheric Sounder (MAS) measured ozone, water vapour, chlorine monoxide and temperatures in the 20 to 200 km region.

The Shuttle Solar Backscatter Ultraviolet (SSBUV) experiment, which was making its fifth Shuttle program mission, was mounted on the payload bay wall in two GAS canisters and is used to calibrate ozone sounders on NASA and NOAA satellites.

Four other instruments were used to study solar science as it relates to the atmosphere. The Active Cavity Radiometer (ACR) and the Measurement of the Solar Constant (SOLARCON) experiments made precise measurements of the total energy that the Earth receives from the Sun. ACR and SOLARCON data will be compared to data from instruments aboard the UARS and EURECA satellites to provide detailed analysis of these parameters. The Solar Spectrum measurement (SOLSPEC) experiment examined how solar energy is distributed in the ultraviolet, visible and near infrared wavelengths. The Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) recorded solar radiation at ultraviolet wavelengths to determine how this energy varies over a solar cycle.

In addition to the SSBUV GAS canisters, STS-56 also carried the Solar Ultraviolet Experiment (SUVE) in a GAS canister on the payload bay wall. The SUVE, a University of Colorado student-run experiment sponsored by the Colorado Space Grant Consortium, measured extreme ultraviolet radiation wavelengths.

STS-56 carried a complement of seven experiments with hardware located in middeck lockers. These included the Commercial Materials Dispersion Apparatus Instrumentation Associates Experiment; Space Tissue Loss; Cosmic Ray Effects and Activation Monitor Experiment; Shuttle Amateur Radio Experiment; the Hand-held Earth-Oriented Real-time Cooperative User-friendly Location-targeting and Environmental system; and also the Radiation Monitoring Experiment. Air Force Maui Optical Site Calibration Test experiments were also conducted but involved no additional flight hardware.

Guildford School Shuttle TV Link

Pupils at the Royal Grammar School, Guildford became the first school outside America, perhaps the first in the world, to have a direct colour TV link with a space shuttle at 6:57 am BST and 8:30 am BST on 9 April 1993. In addition to the TV link up there was voice contact between the shuttle and pupils in the school during two orbits.

The school's reputation for space firsts managed to secure it an official role in the radio experiments being conducted aboard Discovery. The Royal Grammar School was the first school to talk to Helen Sharman on the Russian Mir space station, as well as having digital and voice radio contact with the Atlantis shuttle. Space pictures are received daily in the school's radio room.

NASA's mission control in Houston was in direct contact with the school during the radio link-up with Discovery. Because of attitude manoeuvring of Discovery during the first link-up at 6:27 am BST only a brief voice exchange was possible. The mission director in Houston made the decision to allow a further contact 90 minutes later on the next orbit. The next contact proved to be a triumph. The equipment worked well and there was an interference free radio contact. The TV image sent showed a group of pupils in the radio room and the report back from Discovery was of a good clear picture received. Then three pupils asked questions directly to the astronauts on Discovery. The questions related to potential damage caused to the shuttle by space debris and their onboard atmospheric experiments.

Image as received on Space Shuttle Discovery.

Even though the scheduled contact was in the Easter holiday and at a very early hour of the morning many pupils crowded into the school's radio room for a chance to talk to the space shuttle. It was an exciting event for all concerned. One pupil who returned to Guildford from Gloucester specially for the chance to be involved with the event said it was certainly well worthwhile.

Mr Frank Bell, Deputy Head of Science at the school organised the equipment in preparation for the contact but it was the pupils themselves who controlled almost all of the voice and TV exchange.

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maximum separation distance. After the engine firings Discovery was catching up at a rate of about 14 nautical miles per orbit. Discovery continued its approach throughout the day with a few small alignment adjustments later in the day.

Meanwhile, back on Discovery ATLAS-2 instrument observations continued to go well, and the flight's planned SUVE observations were again made during the day.

SAREX communications with students on the ground continued during the day as well. Ken Cameron used the fast scan television reception feature of the SAREX equipment and radioed down that he could see the flight controllers at Mission Control as Discovery's flight path took it over Houston.

Flight Day Six

The crew successfully retrieved the SPARTAN satellite. After Ken Cameron had eased Discovery up alongside SPARTAN, Ellen Ochoa slipped the Shuttle's robot arm on to SPARTAN's grapple fixture at 3:20 am. SPARTAN was then lowered into the payload bay and locked into place at 4:02 am on April 13. SPARTAN had spent two days in free flight making observations of the solar wind and solar corona without problems.

The STS-56 astronauts continued to contact amateur radios at several schools during the day and to take high resolution photographs of the Earth. A laptop computer used by the HERCULES experiment to identify and append precise geographic locations to Earth observation photographs was replaced and Ken Cockrell made the programming changes that assisted another computer to help store the information. This allowed the crew to make as much use of the HERCULES system as possible.

Mike Foale inspected connections among the computer, antenna and receiver system that received and stored precise positioning data from the Global Positioning System satellite network. This data which was to be used after the mission was completed in order to provide information to verify the orbiter's exact location when the ATLAS-2 instruments recorded their readings.

Flight Day Seven

Discovery's crew performed a standard prelanding checkout of their spacecraft in preparation for the landing which was then scheduled for Flight Day Nine. Later, at 5:09 am the crew took part in an in-flight press conference and answered reporters' questions on their Earth observations, contact with the Mir space station, cooperation with Russia and the ATLAS-2 experiments. Ellen Ochoa also took time out to discuss the flight with several schools during video interviews.

The STS-56 crew used the SAREX equipment to continue their contact with students at various schools and also to receive television views of mission controllers. As the crew watched the mission controllers the controllers were able to watch the crew by standard television sent from the orbiter.

Flight Day Eight

The crew began the task of stowage in preparation for their landing - then set for 7:33 am on the next day. The weather picture for the landing was favourable at the time; however, forecasters were keeping a close watch on the speed of an approaching cold front.

The RMS robot arm was powered down and latched in place along the port side of the payload bay. The ATLAS-2 experiments were deactivated and the cabin was prepared for the landing.

Later in the day, mission controllers determined that the projected weather at landing time would not be acceptable and the April 16 landing was postponed for one day.

Flight Day Nine

Following the landing postponement, astronauts Cameron and Ochoa reactivated Shuttle and payload systems in preparation for additional scientific observations. The one-day landing postponement allowed the crew to obtain about twelve hours of additional scientific data. Following the additional observations, Foale and Cockrell powered down the payload instruments and stowed equipment for the return to Earth.

Flight Day Ten

On Saturday, April 17, Discovery began its landing with a deorbit burn of its manoeuvring engines at about 6:34 am. The approach to the Kennedy Space Center landing site's Runway 33 was normal and the orbiter's main landing gear touched down at 7:37:34 am. The nose gear touched down at 7:38:21 giving STS-56 and official duration of 9 days, 6 hours, 9 minutes and 21 seconds. During its mission Discovery completed 148 orbits of the Earth and travelled approximately 3,853,997 statute miles.

Later in the afternoon the orbiter was transported to the Orbiter Processing Facility where it began its post flight operations and preparation for its next mission - STS-51 which is scheduled for July, 1993. Also later in the day, the flight crew returned to their home base in Houston.

To Florida to Watch a Shuttle Launch: Going to Florida for a holiday launch. For Nienna Tromlin, her Florida trip came about because of

'Friends in

If a friend of the family invited you over to America to watch him fly the space shuttle, would you say no? We did not.

My boyfriend, his father and myself travelled to Florida in January to see Colonel John Casper, a long-time friend of the family, fly on Endeavour, NASA's newest space shuttle. John was to be Mission Commander on this mission, designated STS-54.

BY NIENNA TROMLIN
Bristol, UK

We arrived at the prearranged pick-up point at around 06.30 on the morning of the launch (13 January), and at just after 07.00 the convoy of six coaches departed towards the observation site. Once there we disembarked quickly, descended to the stands that stood by the waterside and settled down to wait for the lift-off. The launch pad was about three miles away, across Banana Creek.

The countdown went without a hitch, and everybody joined in as the clock reached ten seconds to go. At seven seconds they ignited the shuttle's main engines. At two and a half seconds to go the Solid Rocket Boosters were ignited, and once that happened the crew was heading into space whether they liked it or not!

With a couple of seconds to go we saw clouds of steam billowing out from beneath the launch pad, and then the crackling, thunderous roar that is so characteristic of the Solid Rocket Boosters in operation, rolled over us. The noise was powerful enough to shake the metal bleachers beneath us and set up a sympathetic vibration in my solar plexus. Water deadens sound and Banana Creek is over two miles wide at that point, yet the noise was still deafening!

Endeavour rose on a pillar of flame which was almost too bright to look at, and almost as soon as it cleared the launch pad it began its roll manoeuvre, which, when completed, left it hanging upside-down beneath its massive external tank. SRB separation was completed successfully two minutes into the mission, and about four minutes after launch it was announced that the shuttle could no longer return to Cape Canaveral. Shortly thereafter we were informed that the shuttle could now reach orbit even if two of its main engines failed, at which point we were asked to return to our coaches and were ferried back to KSC.

Having seen a launch at first hand makes the memory of the Challenger disaster even more poignant for me, especially because John Casper was the astronaut on duty as Family Liaison the day of the accident. It takes a special type of person to climb into a shuttle, having witnessed one exploding at first hand.

The crew, John Casper, Susan Helms, Greg Harbaugh, Mario Runco and Donald McMonagle completed many experiments during the mission, the most notable being the successful deployment of the Diffuse X-ray Spectrometer (DXS). Early in the mission they launched the fifth TDRS satellite, and later they performed the much publicized 'toys in space' demonstra-

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Society News

SPACE '93

Hastings, E. Sussex

15-17 October 1993

A UNIQUE MEETING TO CELEBRATE 60 YEARS DEVOTED TO THE ADVANCEMENT OF SPACE AND ASTRONAUTICS

SPACE '93 promises to be the leading space gathering of the year in the UK - full of interest and entertainment:

Civic Reception: To be hosted by Hastings Borough Council at the Marina Pavilion at St Leonards-on-Sea on the evening of 15 October. ***Opening Ceremony:*** To be performed by the Mayor of Hastings with a welcome to all participants. ***Space Exhibition:*** To include as exhibitors Matra Marconi, BNSC and Logica. ***Anniversary Dinner:*** To be held on Saturday 16 October to mark the 60th Anniversary of the BIS. Guest speaker will be Professor Garry Hunt. ***Programme of Speakers:*** From the Space Industry, Space Agencies and Research Institutes. ***Hastings-Sri Lanka Intelsat Link-Up:*** With Arthur C. Clarke and Patrick Moore. ***Complimentary Sunday Lunchtime Buffet:*** This will be provided, courtesy of British Telecom, to all participants in the Sussex Hall of the White Rock Theatre which will also be the venue for the satellite link-up.

Accommodation: A special rate for the weekend has been negotiated by the Society with two hotels. Accommodation is limited.

Advance Registration: For information on the programme, accommodation and other arrangements, please contact The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Open to Members and Non-Members. Members enjoy a discount on rates.

"The growth of satellite television channels covering the UK and the rest of Europe has exceeded all original predictions - the London Teleport is at the heart of this industry."

On 31 March a party of BIS members visited BT London Teleport at the Isle of Dogs. The four-acre site was easily located by a forest of dish antennae. Members were welcomed by officers of British Telecom International including Colin Woodward, the Station manager, and were given coffee and temporary visitors' passes.

In the conference room there was a slide projection presentation of the facilities on-site showing both schematic layouts and photographic views. London Teleport, Goonhilly and Madley are the major commercial satellite Earth stations in the UK with the BT Tower at Howland Street, London acting as their switch at the hub of the national communications.

To avoid C band radio interference to or from its close neighbours, the Teleport uses Ku band frequencies for

this year? If you time it right, you might be watching a space shuttle a space shuttle launch and she was not disappointed. Read on ...

High Places'

tion, in which they used children's toys to demonstrate fundamental laws of physics to an audience of school-children. They successfully tested NASA's new 23 million dollar super-loo, and to cap the mission, Greg and Mario performed a dual EVA.

After a six-day mission, the shuttle headed in for a landing at the Cape. A couple of minutes before touchdown it heralded its return with a double sonic boom, which could be heard as far away as Orlando. After that dramatic precursor to the main event, we were all straining our eyes for our first sight of Endeavour.

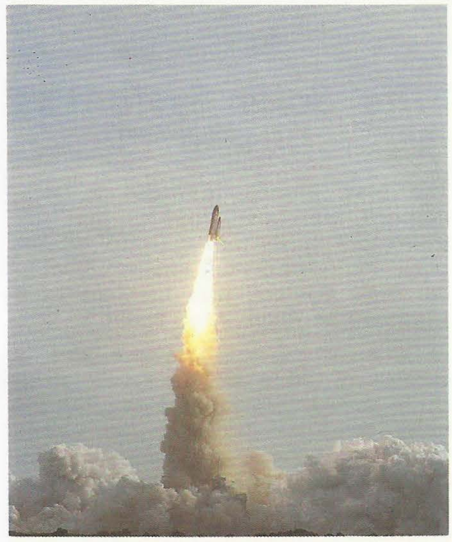
And then there it was, a tiny dot in the sky which grew rapidly. The shuttle has a glide ratio of 1 to 1 which basically means that for every mile it flies it drops a mile. Not for nothing is it known as 'the flying brick' by the astronauts who fly it! The shuttle's angle of descent is much steeper than a jet aircraft, and its landing speed is much higher (over 200 mph), which makes the landing quite spectacular.

Colonel Casper made an almost perfect landing, and the drag chute was immediately released to help slow the shuttle down. The observation stands are only about a hundred and fifty yards away from the huge runway, and by the time Endeavour passed in front of them it had lost nearly two-thirds of its landing speed.

Endeavour came to a complete stop about half a mile from where we were sitting, and was immediately descended on by teams of NASA technicians and scientists, whose job it was to make safe the shuttle, looking initially for possible leaks of toxic chemicals from the OMS engines. Understandably NASA do not want to have the crew's families and friends exposed to toxic chemicals, so we boarded the coaches and headed back to KSC.

For most of the crew-guests that was the end of the day's excitement, but not for all of us. A few of us had been invited to the crew-quarters that afternoon to be reunited with the astronauts. We lucky few were picked up from the car-park at KSC at about 14.00 and were taken to a largish, rather anonymous building located in the industrial area of the Cape. Once there, we were led to a room obviously intended for press conferences, whereupon our NASA tour-guides disappeared discretely.

A few expectant minutes passed before the crew, dressed in dark-blue flight-suits, entered the room, and what followed was a predictably emotional reunion of families and close



Endeavour rose on a pillow of flame which was almost too bright to look at.
Photo supplied by the author

friends.

What I remember most about the reunion was that John was genuinely pleased to see us. That must sound strange, but here was a man who had spent six days in space as Mission-Commander of Endeavour, who had landed the shuttle that morning, and who probably had not slept the night before. He was, understandably, emotionally and physically drained, and yet he was as pleased to see us as we were to see him. That made us feel very special indeed.

Visit to British Telecom

BY ERIC WAINE
Fellow of the BIS

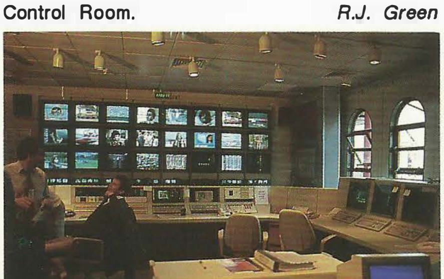
its up and down links with the geostationary satellites. With a monthly electricity bill alone in the order of £22,000, the station must endeavour to give its customers a virtual "no-break" service. In the event of a fault there is the usual automatic switchover to reserve amplifiers, etc. If the main power supply should be interrupted, a reserve diesel-generator set would automatically start up to give a local supply. In the interim, batteries with an hour's reserve capacity would cover any break. The 3 diesel-generator sets allow for the extreme case of one to be in use, one on standby and one out of service during maintenance.

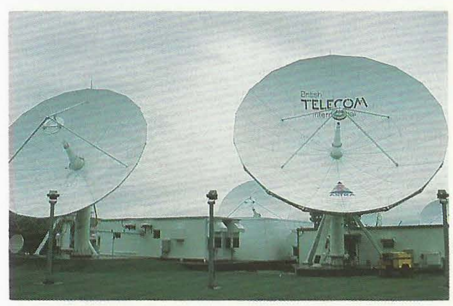
A tour of the site, led by the Manager, revealed many dish antennae large and small, permanent and mobile, working to Intelsat, Eutelsat and other satellites. There seemed little scope for growth but the Manager was confident that a few more antennae could be accommodated. Apparently, high-velocity winds can be troublesome and in 1987 and 1989 there were occasions when the large lightweight dishes had to be additionally tethered to avoid damage. On the infrequent occasions when the Sun is behind a satellite causing some degradation of service, the station forewarns its customers who can then take necessary precautions.

With whetted appetites the group returned to the conference room to tuck into an excellent buffet lunch. Wide-ranging discussion, which had begun following the slide presentation, continued throughout the tour, lunch and afterwards. The visit closed with members thanking Colin Woodward for giving them a fascinating insight into the practical aspects of running commercial satellite services.

Programmes are transmitted from the programmers' studios to the Teleport via the London BT Tower and then via satellite to receiving antennas.

Control Room. *R.J. Green*





Astra Uplink (Old BT Logo). *R.J. Green*

Astronomical Notebook

The Solar System's Most Distant Planet

The Max Planck Institute in Heidelberg, Germany, reports that astronomers have managed to photograph the most distant known object in the Solar System, with the help of a telescope in Calar Alto, Spain.

The small object, estimated to have a diameter of 100 to 200 km has the provisional name 1992QB1. It throws out ten million times less light than the faintest star discernible with the naked eye. Its discovery last summer by the Mauna Kea observatory in Hawaii caused a stir when astronomers estimated it was situated at a distance of more than six billion km and, being beyond Pluto, is the most distant known planet from the Sun.

Satellite Images Support 'Dark Matter'

It has been thought for some time that the observable mass in the universe - stars, planets, galactic dust clouds and so forth - is nowhere near enough to account for the way the universe actually behaves. As much as 95 percent of the mass suggested by calculations is nowhere to be found. It has therefore been assumed that there must be some kind of "hidden" or "missing" mass. The actual nature of the "dark matter" still needs to be identified. As it does not emit radiation it cannot be detected directly by instruments. Now X-ray pictures of a giant gaseous cloud taken by the ROSAT satellite provide indirect evidence.

The ROSAT satellite's X-ray images taken on April 25-27, 1992 depict three galaxies known as the NGC 2300 group, about 150 million light-years from Earth in the direction of the constellation of Cepheus. They show that the small group of galaxies is immersed in a huge cloud of hot gas about 1.3 million light-years in diameter. It appears to have a mass equal to about 500 billion times that of the Sun and is at a temperature of about 18 million degrees Fahrenheit.

"A cloud like this would have dissipated into space long ago, leaving nothing for us to detect, unless it was held together by the gravity of an immense mass", said Richard Mushotzky (NASA's Goddard Space Flight Center). "The mass required to restrain the cloud is about 25 times greater than the mass of the three galaxies together".

This is the first time a multimillion degree gas has been found to pervade a small group of galaxies. In previous observations it was detected only in large clusters of galaxies.

ESA Space Science Projects

Latest Development Status

Infrared Space Observatory (ISO)

ISO, the most complex scientific mission undertaken in Europe, has been dominated by technical problems with the telescope and the liquid helium valves, causing a delay of the target launch date to September 1995.

All satellite flight hardware has been made and integration at the payload module liquid helium cryostat and the service module is well underway. The liquid helium valves are undergoing further development and alternative valves are being tested. Scientific instrument flight hardware has been built and is being delivered for satellite integration.

A new important problem is that of setting up the ground operations of ISO as an observatory to be used by the scientific community at large. Special action is being taken aimed at simplifying the operations and the projects for operating ISO have become more firm. A second station will allow complete coverage of the 24 hour orbit.

SOHO

The SOHO programme is approaching the Critical Design Review planned for the third quarter of 1993. The Structural Model has already completed several tests and final vibration is planned for mid-1993. The Engineering Model integration is complete and the test programme will commence shortly. Flight Model manufacture is well underway with integration planned to commence in the last quarter of 1993. A 1995 launch date has been confirmed.

CLUSTER

The Structural Model test programme is completed with successful qualification for Ariane 5 demonstrated. Engineering Model system testing is well advanced and the integration of the first Flight Model has commenced. Delivery of the four spacecraft is expected in mid-1995 in time for the Ariane 5 V501 launch in late 1995.

The implementation of a distributed Science Data System has commenced to cater for data analysis post-launch. As a part of this a Joint Science Operations Centre is being set up at the Rutherford and Appleton Laboratory to ensure close scientific coordination of the four spacecraft missions.

XMM

The X-ray Multimission situation has improved considerably. The development of the mirror shells technology, which is critical for XMM as there are 58 shells in each of the three telescopes, has progressed considerably.

The launch of XMM by an Ariane-4 rocket is planned for mid-1999.

ESA Selects INTEGRAL

In early May, ESA Advisory bodies recommended the next project to be undertaken under ESA's Horizon 2000 science programme. The project selected from the shortlist is INTEGRAL which was judged to be within the funding available and to offer the prospect of new astrophysical discoveries.

INTEGRAL (INTErnational Gamma-Ray Astrophysical Laboratory) is an international mission to be carried out in cooperation with NASA and the Russian Space Research Institute IKI to follow on two current missions, the Russian GRANAT (flying the French SIGMA telescope) and the American Compton Gamma-Ray Observatory (CGRO). INTEGRAL will have instruments 10 to 50 times more sensitive than those of its predecessors.

Gravitational Wave Search

Three interplanetary spacecraft, heading toward Mars, Jupiter and over the poles of the Sun, may soon prove the existence of elusive waves in the universe's gravitational field.

Gravitational waves have never been directly detected, although their existence was predicted in Einstein's theory of relativity decades ago and there is indirect evidence that they exist. They are believed to be produced by supernovae explosions, collapsing black holes and other catastrophic events but previous searches with ground-based equipment and single spacecraft have failed to discover them.

Astrophysicists are hoping to discover very low frequency gravitational waves with three spacecraft now on their way to separate destinations in the solar system. They are NASA's Mars Observer, Galileo and the European Space Agency (ESA) Ulysses spacecraft.

The experiment is built around a simple concept. During a 3-week period, the antennas of NASA's Deep Space Network (DSN) will beam radio signals to the three spacecraft at precisely known frequencies. Each spacecraft will send signals back to Earth at the same frequency it receives. If no gravitational waves are passing through the Solar System, the signals returned to Earth should have exactly the same frequencies as the original signals sent from the DSN, shifted only by the Doppler effect.

However, if a strong enough gravitational wave passes both the Earth and the spacecraft, the latter will experience a slight "bobbing" from the ripple-like passage of the wave and a slight change in the frequency of the radio signals finally bounced back at Earth will arise.

Hubble Holds Key to Galactic Evolution

A principal goal for the Hubble Space Telescope is to trace galactic evolution through direct observations. New data show early influences on the form of galaxies. More key results are expected when the full Hubble optical capabilities have been restored. (See *'What is COSTAR?'* on p.196).

NASA's Hubble Space Telescope (HST), looking far away and far back in time, has found suspected ancestors of today's galaxies. Its pictures reveal that star-forming galaxies were far more prevalent in the younger universe than in modern clusters of galaxies, results which have an important bearing on theories of how galaxies have evolved since the beginning of the universe, 15 billion years ago.

Serendipitously, the Hubble observations might have also discovered the most distant galaxy cluster yet. It might be as far as ten billion light-years, a time corresponding to the early epoch of galaxy formation.

Images of a pair of remote clusters of galaxies four-billion light years away have shown, for the first time, the shapes of galaxies which existed long ago.

The pictures, taken with HST's Wide Field/Planetary Camera, are so detailed that they show a full range of galaxy types inhabiting the universe four billion years ago: in elliptical, spiral, distorted and irregular forms. They also reveal galaxies in collision, with some tearing material from each other and others merging into single systems.

The pictures are sharp enough to distinguish between various forms of spiral galaxies, whose distinctive swirl patterns are outlined by vigorous star formation. This suggests that billions of years ago clusters contained not only the elliptical and S0 galaxies (S-zero, lens-shaped featureless galaxies that may be the transition between spiral and elliptical) like those dominating their descendant clusters today, but also several times as many spiral galaxies.

Disappearing Galaxies

"The new Hubble data are the first unambiguous sign of the influence of the environment on the form of a galaxy" said Dr Alan Dressler of the Carnegie Institution. "Clearly, spirals were common in clusters in the distant past but they have largely disappeared or changed form by now".

The question arises as to what has been responsible for their demise? Based upon the HST pictures and results of earlier research with ground-based telescopes, the rapid decline in the spiral population may be explained by three mechanisms: merger, disruption and fading.

HST reveals many examples of strong galaxy interactions or mergers in one of the clusters. This is evident by the presence of "tails" distorting the shapes of some galaxies. The tails are probably caused by tidal effects where the close gravitational pull between bypassing galaxies stretch and disrupt their stellar distributions. The result is that many ancient spirals might have merged to form giant elliptical galaxies or simply been torn apart and dispersed. However, violent collisions may not be the whole story of the missing spiral galaxies. Earlier research has indicated that bursts of star formation were also much more common in the past. When the star formation subsided in many of these early spiral galaxies, they may have faded so that they are unnoticed in today's nearby clusters.

The Most Distant Galaxy Cluster?

HST observations may have discovered the farthest cluster of galaxies ever seen, located ten billion light-years away. It resolved a cluster of about 30 very faint objects. The smaller, more compact appearance of the objects suggests that they are in the background, much further away than the foreground galaxies. Additional evidence comes from the presence of a possible quasar among the faint objects. Ground-based spectral observations of the quasar's redshift (an indicator of cosmological distances) place the quasar at a distance of ten billion light-years. Quasars were extraordinarily bright, active cores of primordial galaxies. They were prevalent in the early universe so most are located far away.

Remote clusters of galaxies which existed when the universe was two-thirds of its present age.
Alan Dressler, Carnegie Institution/NASA

The bright spots which might accompany the quasar do not resemble the elliptical and spiral galaxies of today. These objects might not be separate galaxies but rather 'hot spots' in galaxies whose full, extended forms are too faint to be seen.

If the small spots seen in the more distant cluster were sites of vigorous star formation, this would explain their blue colours, because young, massive stars are brightest in blue and ultraviolet light.

When its full optical capabilities are restored during a Space Shuttle servicing mission in late 1993, HST will be able to resolve the morphology of these very young galaxies. Hubble will be capable of showing galactic evolution over a wide range of environments and in even earlier epochs.

The Mystery of Galactic Evolution

Charles Messier first included galaxies in his sky catalogue of "fuzzy-looking" objects in the 1770s. At that time their true nature was not known and it was not until the 1920s when Edwin Hubble, using a telescope of a comparable size to the HST, was able to measure the vast distances to nearby spiral nebulae. This proved them to be island universes, far separated in time and space. Edwin Hubble then attempted to classify galaxies according to their spiral and elliptical shapes in order to look for an evolutionary track.

The 1960s saw a number of remarkable discoveries. Quasars, active galaxies and confirmation of the "Big Bang" by the detection of the cosmic microwave background converged to reinforce the notion that galaxies were not always as seen today but evolved into their present shapes.

H. Butcher and A. Oemler surprised the astronomical community in 1978 when they discovered that distant clusters contained a higher percentage of blue galaxies, a colour associated with the birth of new stars in spiral galaxies. In contrast, nearby "modern" clusters of galaxies are dominated by elliptical and S0 galaxies, objects whose red colour indicate a long absence of star formation.

The question of whether there were more spiral galaxies in clusters billions of years ago was pursued by A. Dressler and J. Gunn in a ten-year programme using the 200-inch telescope at Mt. Palomar Observatory, California. They took spectra of the faint blue galaxies which showed that most did show signs of vigorous star formation.

HST Shows Structure of Interstellar Medium

A recent HST image has shown, with unprecedented clarity, the structure behind the shock waves in the famous Cygnus Loop supernova remnant thus allowing for the actual structure of the shock to be compared with theoretical calculations for the first time.

The supernova shock wave compresses and heats the interstellar gas, causing it to glow. The shock acts as a searchlight by revealing the structure of the interstellar medium.

The Cygnus Loop indicates the edge of a gigantic bubble-like, expanding shock wave from a colossal stellar explosion which occurred about 15,000 years ago.

SPACE PROBE DIARY

Cassini-Huygens

1 May

Major modifications made by NASA to the Cassini Spacecraft have resulted in the use of the High Gain Antenna for communications during the Probe mission. Thus the data are to be stored on board the Cassini Spacecraft in the Solid State Recorder and subsequently transmitted to Earth.

Launch is still expected in October 1997.

Galileo

3 March

Any real hope of fixing the stuck antenna dish was given up in January after it had been thumped 13,320 times with motors designed to open the device. Although the spin rate has been trippled from 3.15 rpm to 10.5 rpm for other reasons, the antenna still failed to open.

The antenna was designed to unfold into a 16-foot-wide dish that looks like an upside-down umbrella with 18 ribs and it is believed that three of the ribs are stuck to a central tower.

Galileo depends now in its much smaller antenna dish to transmit data from Jupiter during 1995-97. NASA says it still expects to accomplish 70 percent of the mission's scientific goals even though only 2,000 to 4,000 pictures will be returned instead of the planned 50,000.

The spacecraft fired its thrusters recently to target its flight past asteroid Ida on August 28.

Galileo will return to its normal spin-rate shortly. This was increased mainly as a test for July 1995, when the spacecraft will deploy a 760-pound probe. The probe must spin fast enough to stay stable as it completes its own journey to Jupiter.

9 March

Spacecraft performance and conditions are excellent except for the antenna problem. A 2.1 m/s trajectory-correction manoeuvre was performed on March 9. The Jupiter mission and the August 1993 encounter with asteroid Ida will now depend on the low-gain antenna.

Magellan

22 March

Magellan has completed 7042 orbits of Venus since August 10, 1990 and is 64 days from the end of Cycle 4. The spacecraft continues to operate normally, gathering gravity data in its fourth 243-day cycle of Venus. Magellan has operated using low rate gyro biases through most of the mission to date, so it has not been necessary to calibrate the gyros in high rate mode. However, the aerobraking experiment, to start in late May, has a moderate probability of pushing the attitude control into the range where the high rate mode is needed.

Magellan is continuing its survey of the gravitational field of Venus, utilising precise navigation of the spacecraft in the near-Venus portion of its elliptical orbit until May 15, 1993.

Manoeuvres to circularise the orbit begin on May 25.

Mars '94 Mission

2 March

The Russian MARS '94 mission has been scaled back to the two original landers, one of which will carry an American experiment. A proposal has been advanced for a small 15 lb American mini-rover to be carried piggyback on Russian rovers on the 1996 launch.

2 April

NASA and the Russian Space Agency sign a contract to fly two US Mars Oxident Experiment Instruments on the MARS '94 Mission. The mission, for launch in November 1994, will deploy small landing stations and penetrators and carry a complement of instruments to study the surface and atmosphere of Mars.

NASA also plans, if funding allows, to purchase an engineering model of the MARS '94 Station to be used in performing integration tests with US-supplied flight instrument systems now in preparation.

Mars Observer

18 March

Mars Observer spacecraft completed its third trajectory correction manoeuvre thus setting the stage for approach and capture in Mars orbit on August 24, 1993.

Four of its small 22-Newton thrusters were fired to achieve the desired change in velocity of 1.4 feet (0.46 metres) per second. Preliminary engineering data indicated that the 17-second manoeuvre was successful but a fourth TCM will be performed 20 days before orbit insertion if necessary.

All spacecraft subsystems and instrument payload are performing well in the outer cruise configuration. Uplink and downlink communications are being performed *via* the high-gain antenna.

Since activation of the high-gain antenna in early January, JPL has been conducting a Ka-band communications link experiment. The experiment will evaluate communications capabilities using shorter, 9 mm-long wavelengths rather than the 3.5 cm wavelengths (X-band) currently used. The experiment, the first of its kind, was made possible with advanced technology deployed at the Goldstone 34-metre research antenna. Early results have been excellent and the spacecraft will be periodically tracked at Ka-band throughout the mission.

Mars Observer is now about 18 million miles (30 million kilometres) from Mars, travelling at a velocity of about 7,500 miles (11,000 km) per hour with respect to Mars. One-way light time to Earth is about 7.5 minutes (444 seconds).

Mars Observer is participating with Galileo and Ulysses in the joint gravitational-wave experiment. A small (0.46 metre-per-second) trajectory correction manoeuvre was completed on March 18. The Project has determined that propellant reserves will allow a faster-than-planned transfer to the final Mars orbit, allowing science observations to start November 22, 1993, three weeks earlier than planned.

Mars Observer was launched abord a Titan III/TOS vehicle on September 25, 1992.

Pioneer 12

24 March

Pioneer 12, which had been orbiting Venus for 14 years, burned up shortly after entering the planet's atmosphere on October 8, 1992 - when it ran out of fuel.

In its final hours it produced evidence of oceans on early Venus. The final data indicate that the arid, searingly hot planet was once covered with 3.5 times as much water as thought earlier - enough to cover the entire surface to a depth of 25 to 75 feet. Liquid water could have existed on the surface of Venus for a period as long as a billion years, long enough for life to develop. However, it is believed that Venus' early oceans vaporised and 'blew off' 3 billion years ago in a runaway greenhouse effect when the cool early Sun increased its luminosity and made the planet very hot.

The oceans evaporated, solar ultraviolet radiation split the water molecules into hydrogen and oxygen, and the hydrogen was lost to space. Earlier data showed that Venus heavy hydrogen, or deuterium, is 150 times more abundant relative to ordinary hydrogen than anywhere else in the solar system. Scientists take this as "clear evidence" that Venus once had at least 150 times as much water in its atmosphere as it does today because, although the water's ordinary hydrogen escaped, most of the deuterium has remained. When Pioneer made its final descent to unexplored regions only 80 miles above Venus' surface, it found evidence for 3.5 times as much water as previously suggested by the deuterium ratio.

Ulysses

2 March

The spacecraft is in a highly inclined solar orbit,now more than 20 degrees south of the ecliptic plane and in transit from its Jupiter gravity assist in February 1992 toward its solar polar passages in 1994 and 1995. Spacecraft condition and performance are excellent and cruise science data-gathering continues. The Ulysses spacecraft was built by ESA and launched on October 6, 1990 aboard Space Shuttle Discovery with IUS and PAM-S stages.

Voyager 1 and 2

30 March

The two Voyager spacecraft continue their interstellar mission with fields-and-particles data acquisition. Voyager 1, launched September 5, 1977, is currently 4.8 billion miles (7.74 billion km) from the Sun after flying by Jupiter and Saturn in 1979 and 1980. Voyager 2, launched August 20, 1977, with flybys of Jupiter (1979), Saturn (1981) and Neptune (1989), is now 3.7 billion miles (5.94 billion km) from the Sun.

SPACE AT JPL

Radar Images of Asteroid Toutatis

BY DR WILLIAM I. McLAUGHLIN
Jet Propulsion Laboaratory, California, USA

The best-ever images of a near-Earth asteroid were obtained from Earth in early December 1992 using radar techniques. The asteroid 4179 Toutatis, discovered in 1989, was 4 million kilometres from Earth at the time and was found to be a contact binary, consisting of two irregularly shaped, cratered objects about 4 and 2.5 km in average diameter and rotating with a period between 10 and 11 days. The binary nature of the asteroid was not totally unexpected since 4769 Castalia, imaged by radar in August of 1989, was also found to be a contact binary. However, the result carries significant implications for understanding the origin and evolution of near-Earth asteroids. Dr. Steven J. Ostro of JPL led the radar team that has carried out these epochal investigations of Toutatis and Castalia.

The radar observations were initiated by illuminating Toutatis with 400,000-watt radio transmissions from the 70m antenna located at the Goldstone station of the Deep Space Network. Then, after about one-half minute, approximately 10®25 watt of the original signal, modified by the topography and motion of the asteroid, was captured by a 34m antenna at Goldstone.

To gain some idea of how the radar transmissions were modified by their encounter with Toutatis, consider first the simple case where the asteroid is represented by a perfect sphere, rotating about its spin axis and revolving about the Sun. With a little visualization, one can see that loci of equal distance ("range") from Goldstone are marked by circles on the spherical surface of the "asteroid", circles which are concentric about the line-of-sight from the antenna to the centre of the asteroid. (Ranging information is obtained in practice by encoding time tags into the radar transmission and then noting how long it takes for each labelled pulse of energy to bounce off the target and return to Earth.)

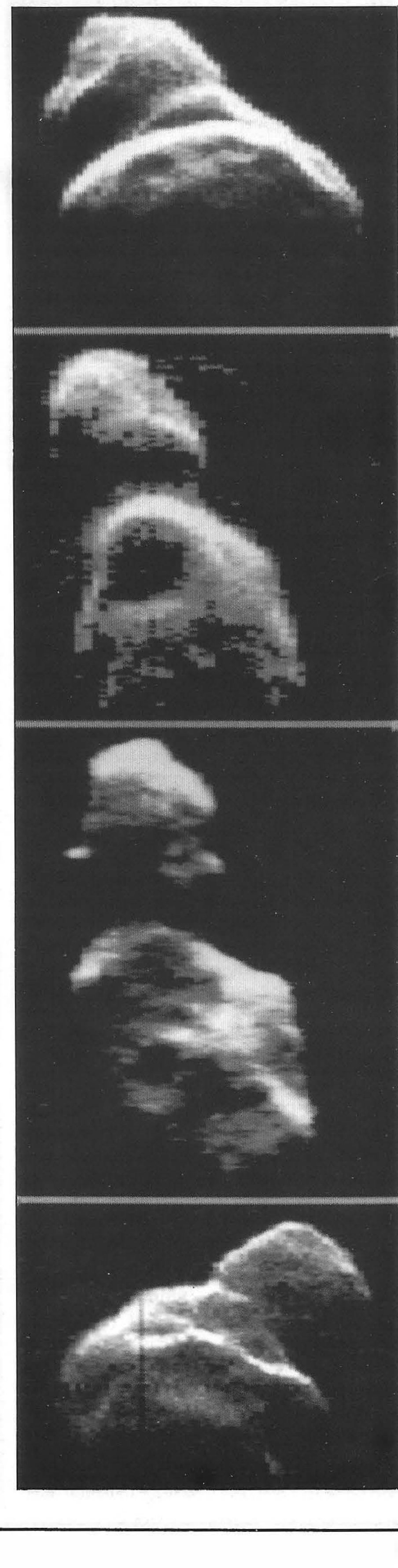
Now suppose there was in fact a single irregularity on the surface of this asteroid, a depression or elevation with respect to the otherwise spherical surface of the body. The resultant ranging information (watts returned versus distance to the surface) would be different from the purely spherical case. But how can this fact be turned into a map of the surface?

The answer lies in noting that not all of the information inherent in the signal has yet been extracted. The transmitted signal had a known frequency, and when this signal is reflected by the rotating asteroid (ignore the revolution of the asteroid and the motions of the Earth since they can easily be accounted for through analysis) new frequencies will be introduced: a Doppler effect. Exercising your visualization faculty one more time, intersect, at an instant, a geometric plane parallel to the asteroid's spin axis and edge-on to the observer, with the surface of the rotating spherical body. This circular locus on the surface of the sphere has the property that all (visible) points on it appear to be approaching or receding from the observer with the same speed.

By means of these two thought experiments the surface has, in effect, been gridded with loci of constant range and of constant frequency.

Thus, the small irregularity that was hypothesized can be localized to one of two points where the appropriate frequency (circular) locus intersects the appropriate range (circular) locus. (Sorry, this requires a third, rather easy, visualization; draw a picture!) In the real case, the surface of the asteroid is modeled by a mathematical expression ("spherical harmonics") whose defining parameters are determined by selecting numerical values for them that best explain the ranging and Doppler information impressed by Toutatis on the radar signal. (Rotational properties are also determined in the analysis of the data.) The approach has conceptual similarities with the determination of the parameters of a spacecraft trajectory through ranging and Doppler tracking.

After this excursion into the dry and possibly stressful realm of analysis,



These are radar images of asteroid 4179 Toutatis made during the object's recent close approach to Earth. The images reveal two irregularly shaped, cratered objects about 4 and 2.5 kilometres (2.5 and 1.6 miles) in average diameter which are probably in contact with each other. the four frames shown here (form top to bottom were obtained on December 8, 9, 10 and 13 when Toutatis was an average of about 4 million kilometres (2.5 million miles) from Earth. The time required to obtain each of these images was 55, 14, 27 and 85 minutes, respectively. On each day, the asteroid was in a different orientation with respect to Earth. In these images, the radar illumination comes from the top of the page, so parts of each component facing toward the bottom are not seen. The large crater shown in the December 9 image (second from the top) is about 700 metres (2,300 feet) in diameter. The radar observations were carried out at the Goldstone Deep Space Communications Complex in California's Mojave desert by a team led by Dr Steven Ostro of JPL. For most of the work, a 400,000-watt coded radio transmission was beamed at Toutatis from the Goldstone main 70-metre (230-foot) antenna and relayed back to the 70-metre station where they were decoded and processed into images. The radar observations were part of the Planetary Astronomy Program of NASA's Office of Space Science and Applications.
NASA/JPL

let us look into the fruits of the investigation.

The two irregularly shaped, cratered components of Toutatis show some morphological similarities with other small bodies in the solar system, such as the asteroid Gaspra. The irregularity of shape is, of course, quite easy to understand since the gravitational forces of these objects are not sufficient to dominate their intermolecular forces. Moreover, the cratered and jagged appearances bespeak a history of collisions. Although collision rates in the solar system vary through time and space, the evidence shows that getting "knocked about" is quite common. An apparently undisturbed surface in the solar system is generally one that has benefitted from the action of cosmetic processes. These include erosional processes and plate tectonics on Earth, volcanism on Venus (an activity that has left scars of its own), and the "instant" healing practiced by Earth's oceans and the atmospheric cloaks of the four gas giants, Jupiter through Neptune.

According to Ostro, the binary nature of Toutatis may be the most important result of the radar experiment. It is important from a statistical viewpoint in that now about six asteroids show evidence of bifurcation under examination by radar. This represents approximately 20% of the set of near Earth asteroids that have been observed with radar. It is important, also, for understanding the collisional processes that may operate in the domain of small bodies.

It is probable that the two components of the asteroid came together in a relatively gentle collision, Ostro said, but events prior to this conjunctive event are less certain. Toutatis could have resulted from a catastrophic collision in the main belt of asteroids, located between Mars and Jupiter, with some of the debris being injected into near Earth orbit to furnish material to be united into the present binary asteroid. Another scenario envisages Toutatis as the product of a collision which split its parent body in two but the impact was not strong enough to pulverize or scatter the fragments.

Analyses of the special case of two equal-sized asteroids colliding with each other have shown that different regimes of collision products exist and depend upon a combination of the diameters and velocities of the objects. For example, asteroids of any size approaching at a few kilometres per second would experience a catastrophic collision with dispersal of the fragments. Small asteroids (100m or less) with low approach speeds would tend to rebound from one another, while larger ones, still at low approach speeds, would join into a binary pair (such as Toutatis). A fourth regime encompasses asteroids larger than about 100km colliding at relatively low speeds; a single body reassembled from fragments of the collision may result. The collisional regimes are more complex than could be described in these few words, and the reader is referred to William K. Hartmann's paper in the book *Asteroids* (pp. 466-479, edited by Tom Gehrels, U. of Arizona Press, 1979).

Ostro foresees rapid progress in the observation of near Earth asteroids. Two factors feed this growth: (1) increasing numbers of asteroids are being discovered (by optical methods, see for example the work of JPL's Eleanor Helin as outlined in the January 1989 edition of this column), and (2) observational facilities are being upgraded dramatically.

In the second category, the giant 305m antenna at Arecibo in Puerto Rico will, in a few years, have a megawatt of power available for asteroid observations. Even if no new near Earth asteroids were discovered, this system would permit one or two Toutatis-like observations per year. However, postulating reasonable rates of discovery, one can expect four or five opportunities per year to exist by late in the present decade, increasing to once per month early in the next century.

The class of near Earth asteroids comprises, for Ostro, more than just an occasion for scientific research. "I am enchanted with these minor worlds, our closest neighbours in space." He notes that we have barely begun to discover this swarm and that they will eventually become a piece of human civilization, part of our consciousness and part of our economy.

Although the Moon and Mars have historically been the foci of solar-system attention, more neighbourly entities now compete for attention, e.g., geosynchronous orbit as a roost for communications satellites (a concept proposed by Arthur C. Clarke in 1945) and the magnetosphere in which we are wrapped (explored in part by Dr. James Van Allen using JPL's Explorer I satellite in 1958). It seems not unlikely that these rocky companions, near Earth asteroids, will also enter the inventory of our civilization.

Discovery-Class Missions

The exploration of the solar system with automated spacecraft has yielded some of the most tangible benefits of human investment in space. From the first successful interplanetary mission, Mariner 2 to Venus, launched in 1962, to Ulysses, Galileo, and Mars Observer, now in cruise prior to accomplishing their prime missions, this set of electromechanical probes has brought us scientific knowledge and the sense of adventure that comes from exploration. The space community in the U.S. has felt for some time that it would be highly desirable to find a way to pursue some aspects of solar-system exploration with low-cost, frequently conducted missions. To this end, NASA has initiated the "Discovery Program".

Mariner 2 is more than an object of historical interest; it demonstrated by example how valuable science can be obtained at low cost. Even without benefit of the micro-electronics which we enjoy today, the flight system of Mariner 2 had a mass of only about 200 kg, and less than 10% of this total was devoted to the set of scientific instruments.

One might object that reaching to the distant past for an example is not valid because Mariner 2 was exploring almost unknown domains and could not fail to find phenomena of great interest. Such an objection is fair enough but the Discovery Program plans to assure value by mandating focused science.

Focusing an investigation on a limited set of scientific questions creates a situation where, if the questions are insightfully chosen and the mission is intelligently constructed, the results must have value. Focusing is now feasible because previous solar-system missions have, in many areas, provided tantalizing glimpses of deeper structures and processes. Moreover, the association of low-cost implementation with a constricted scenario is plausible; historically, multipurpose spacecraft with richly textured missions have proved to be more costly than their less-complex brethren.

The niche which the Discovery Program seeks to occupy is not the only neighbourhood in the realm of space science, and, certainly, other programmes have formulated similar approaches.

With regard to the latter point, the Small Explorer (SMEX) programme, which the Goddard Space Flight Center manages for NASA's Astrophysics and Space Physics Divisions, also is directed toward focused sets of scientific questions utilizing low-cost missions. (The first SMEX, the Solar Anomalous and Magnetospheric Particle Explorer, was launched in July 1992.)

Another low-cost example is provided by the International Cometary Explorer (ICE) of NASA which conducted the first space encounter with a comet, Giacobini-Zinner, in 1985.

(See the January 1986 "Space at JPL".) The spacecraft was diverted by Dr. Robert Farquhar and his colleagues at NASA/Goddard from sentinel duties as the International Sun-Earth Explorer 3 (ISEE-3) and sent to the comet by a deft series of motor burns and Earth-Moon gravity assists.

One admires the skill and ingenuity of our colleagues in the European Space Agency (ESA), who, for example, in their moderate-size series of missions have established a framework for major scientific returns at modest cost. The "M1" moderate-size mission of ESA is the Huygens Probe, which will be inserted into the atmosphere of the large satellite Titan as part of the Cassini mission to Saturn (1997 launch).

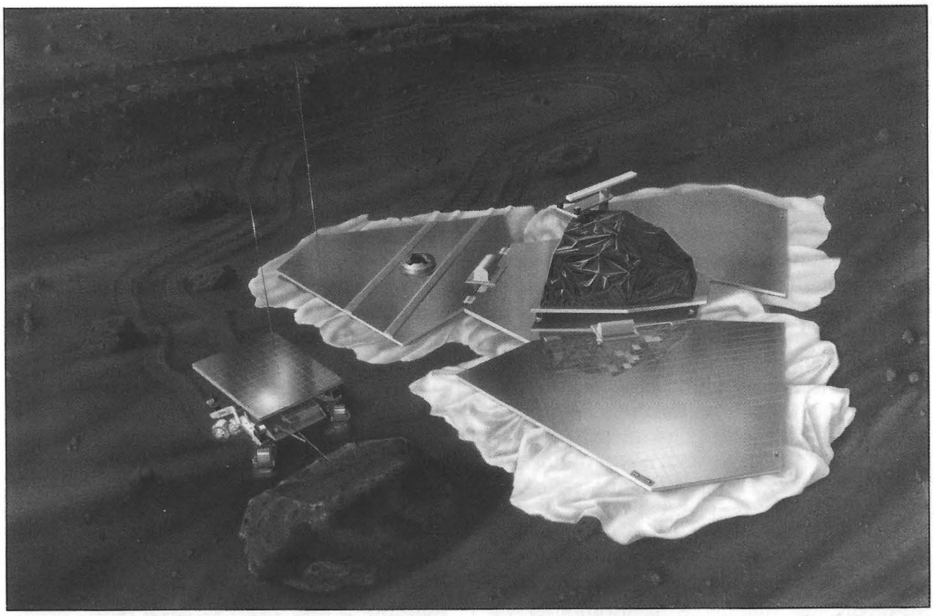
The above list is by no means meant to be exhaustive, but the Japanese lunar satellite Hiten, put into orbit about the Moon last year, must also be included in any enumeration of cost-effective missions. After launch in January of 1990 into Earth orbit, Hiten was moved to an orbit about the Moon in February 1992 and impacted the lunar surface in April 1993, concluding a series of experiments on gravitational control of satellites.

Although focused missions are very attractive, wider-ranging investigations have a place in a balanced programme of space science. Galileo, now in cruise to Jupiter, and Cassini will supply spectacular views of the two largest planets in the solar system. To appreciate some of the scientific competence of Galileo's payload, read Kelly Beatty's article in the April 1993 issue of *Sky and Telescope*, where selected results of the December 1992 flyby of the Earth-Moon system are reviewed.

The Discovery Program is managed by NASA's Solar System Exploration Division. The first two missions in this proposed series are the Mars Environmental Survey (MESUR) Pathfinder and the Near Earth Asteroid Rendezvous (NEAR), whose advanced-study phases are being conducted at the Jet Propulsion Laboratory and the Applied Physics Laboratory, respectively. ("Pathfinder" signifies that the mission is a precursor to the full-up MESUR: more on this below.) The third and following Discovery missions will be selected through NASA'S "Announcement of Opportunity" (AO) process, commencing in 1994, if funding permits.

The launch frequency for Discovery missions is planned to be every two or three years with MESUR Pathfinder targeted for a new start (government approval) in 1994 and a launch in 1996. The expenditure for each Discovery mission, exclusive of launch vehicle and ground operations, is limited to $150 million.

NASA is encouraging the formation of consortia between federal centres, universities, and industry to manage and implement individual Discovery missions. An innovation in management, after MESUR Pathfinder and NEAR, is the designation of the Principal (scientific) Investigator (PI) as the primary responsible individual. Normally, a NASA flight project is managed by an individual at a NASA centre to whom the scientific leader reports (or is coequal with).



The proposed MESUR Pathfinder mission would parachute a station to the surface of Mars, lessening the shock of landing with air bags. Power for the station is derived from solar panels, and a small rover is part of the package. *NASA/JPL*

The process for identifying future Discovery missions attracted 73 concept proposals which were evaluated in November 1992 at a NASA workshop in San Juan Capistrano, California. After brief presentations, panels of experts assessed the missions (whose written proposals had been received earlier), and 14 of the 73 candidates will be funded for further study. (These missions compose a base for response to the AO; other proposers are encouraged to respond.)

The 14 proposals represent a broad spectrum of investigation with two missions to Mercury, two to Venus, two to Mars, six to small bodies, one Earth-orbital telescope, and a solar-wind sample return.

The MESUR project, if approved, will establish a network of small landers on Mars. The MESUR Pathfinder project is intended to be a one-node precursor to the MESUR network as well as the first element in the Discovery Program. Its primary technological objective is to develop and demonstrate delivery capability to the surface of Mars within cost constraints.

Upon arrival at the Red Planet in 1997 and direct entry (as opposed to establishing an orbit prior to entry) into the atmosphere, the vehicle will be braked by aeroshell, parachute, and airbag. Unlike the Viking landers on Mars and the Surveyor and Apollo landers on the Moon, MESUR Pathfinder is being designed with the capability to right itself after touchdown. This action is effected through the deployment of petals which, conjointly, expose solar arrays for electric-power generation.

The strawman scientific payload for MESUR Pathfinder includes instruments to measure atmospheric properties during descent, a camera to obtain panoramic views of the surface, and a spectrometer to analyze the composition of the Martian surface in the vicinity of the lander. The reach of the spectrometer will be enlarged through mounting it on a small rover. The total weight of the rover will be about 6 or 7 kg.

The most visible manifestation of space activity is the flight project, such as Voyager, the Hubble Space Telescope, or, one hopes, MESUR Pathfinder. A programme, which is a set of projects united by a common logic, is in some ways more difficult to compose than a project. The logic must capture the scientific, technical, economic, and political realities that are forecasted to hold during the life of the programme. One of the most successful programmes to meet these conditions was the set of Apollo missions to the Moon, but even Apollo was forced into "earlier retirement" when the national environment changed after ten years.

The Administrator of NASA, Daniel Goldin, has pushed for missions that are "faster, better, cheaper," a prescription that not only fits present conditions but also has a rather enduring ring to it. The Discovery Program, in turn, appears to match Goldin's template and may become a bright path to the future of solar-system exploration.

Regulus and Space Education

Although a positive correlation of space exploration with educational achievements is a plausible phenomenon, it can be instructive to examine some of the causes of this relation. In particular, there are reasons for believing that the linkage between space and education may be quite fundamental and applicable through the full range of educational endeavour.

An obvious causal factor is the cornucopia of raw material for teaching that has been gathered by space missions of discovery and exploration. The film-noir record of astronauts reconnoitring the dry, ancient Moon with our contrasted water planet as backdrop is a unique legacy of the Apollo missions. Voyager's clean images of the giant planets fill the textbooks of students. The venting nucleus of Halley's comet stands revealed by Giotto.

Influential as powerful images may be, in rippling through society, further advantages can be accrued for educational purposes by designing programmes to target specific areas. NASA has a strategic plan for education with a vision "to promote excellence in America's educational system through enhancing and expanding scientific and technological competence."

In order to implement the vision the plan includes several programmes in which JPL and the other NASA centres participate.

For example, the NASA Educational Workshop for Math and Science Teachers (NEWMAST) brings selected teachers, from across the country to observe ongoing activities at JPL (and other centres). Last summer I had the opportunity to present our astrophysics programme to a NEWMAST group and, in the process, became aware of their fortnight's curriculum: this is a substantive programme.

Another example is furnished by the Laboratory's Teaching Resource Center. This facility is located in the nearby community of Glendale and makes available to teachers curriculum guides, posters, software, videotapes, and other teaching aids and materials.

The initiative of individuals complements formal components of the educational programme. The JPL Public Education Office maintains a database of over 400 people who can be matched with requests for JPL personnel on a case-by-case basis. I am acquainted with several people who, over a period of years, have shared their knowledge of space projects with the outside world; my colleague Bob Brooks has played key roles on Voyager and, now, on Mars Observer and has been willing to give freely of his own time to speak and interact in other ways with the public.

Programmes and the teachers who implement them are the core of any educational system. But I promised an analysis of some of the deeper-lying strata of the educational enterprise, and now it is time to deliver.

The Irish statesman and philosopher Edmund Burke (1729-1797) is remembered today primarily for his influence on political thought. His "Philosophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful", published in 1757, helped to shape the thought of the eighteenth and nineteenth centuries on the effects of art and nature on human sensibility.

Mark the word "sublime" in the title of his treatise. In contemporary usage the word has little force, being employed in phrases such as "sublime indifference" and "sublime conception"; it serves to pay a polite compliment to the idea under consideration. For Burke and his contemporaries, and for a few surrounding centuries, "sublime" denoted an important concept; it was used to label those occasions which carried feelings of wonder, awe, immensity and the like. The early minutes of the film "2001: A Space Odyssey" with the thunderous music of Richard Strauss accompanying the alignment of celestial bodies are sublime. The roar of an Earth-shaking Saturn rocket carrying astronauts to the Moon is sublime in this sense, as is Voyager 1's 1979 image of giant Jupiter with Io and Europa suspended in the foreground.

Joseph Addison (1672-1719) wrote a famous series of essays with Richard Steele (1672-1729), appearing in the popular periodical "The Spectator". This versatile English essayist and politician formulated many of the basic issues and concepts associated with the sublime in his essay "On the Pleasures of the Imagination," which ran in "The Spectator." The German Philosopher Immanuel Kant (1724-1804) felt the subject of the sublime so important that he devoted considerable attention to it in his seminal work on aesthetics, *Critique of Judgement*.

The point is that the concept of the sublime fills an important chapter in the history of ideas. As far as I know, the sublime *per se* fell out of fashion rather than suffered judgment as useless or logically flawed.

Before linking the sublime to space education, I must touch on a second subject: systems of common reference.

The Tate Gallery lies on the north bank of the Thames and within walking distance of the Headquarters of the British Interplanetary Society, via Vauxhall Bridge. The painting *Regulus* by J.M.W. Turner (1775-1851) hangs in the Tate and exerts a powerful effect on me at every visit to that institution. And, indeed, it was composed by Turner as a work in the tradition of the sublime. (The book *Turner and the Sublime* by Andrew Wilton, U. of Chicago Press, 1980, treats not only Turner but the full range of the concept of the sublime.)

With respect to composition, *Regulus* is centred on the fiery Sun, which floods the picture with light from its position near the horizon. The title of the picture is derived from the Roman general of that name who participated in the first of three Punic Wars, wars which were fought between Rome and Carthage for supremacy in the western Mediterranean. The panorama of the ancient city which is being blasted by the Sun and the name "Regulus" would evoke a host of thoughts to the classically educated viewer of the nineteenth century.

The classical world of Greece and Rome, portrayed as history or mythology, along with Biblical history, provided a common frame of reference for the educated public for several hundred years and well into the nineteenth century. For example, it was not unusual to quote a phrase in Latin from the Roman poet Horace (65-8 B.C.) in everyday conversation and expect both the phrase and the relevance of the allusion to the situation to be understood.

Turner, by wedding the intense, sublime aspect of *Regulus* to the intelligible world of Roman history, succeeded in the almost paradoxical attempt of expressing immensity in terms comprehensible to a human.

Our age is not alone in its appreciation of the sublimity of the images and concepts of space. Addison says "If we ... consider the fixed stars as so many vast oceans of flame, that are each attended with a different set of planets ... we are lost in such a labyrinth of suns and worlds, and confounded with the immensity and magnificence of nature." However, the common frame of reference is no longer the classical world but, starting its phase of rapid growth in the seventeenth century, has become science and the technology it confers upon us. Due to the mass media and the everyday benefits of technology, this frame of reference is probably supported on a wider base of the population than was that of the classical frame.

The parallel to space education is straightforward. The modern *Regulus* can be represented, for example, by an image of blue Neptune as Voyager 2 sped over its northern polar region in 1989. The pictures of the Neptunian system are sublime, and – note well the difference from the older paradigm – the common (science and technology) frame of reference is not just a mediating agent for the image; the frame of reference was, in fact, used to create the image it cradles!

The upshot of all this is that there are historical and theoretical reasons for believing that utilization of the exciting results of space exploration may strike deeper than we have imagined. Let us not lightly categorize "pretty" pictures and astonishing facts as only a prelude to education; they are welded to the very structure of the enterprise.

As a corollary, the concept of the sublime bears reviewing with respect to its value for our time. In his column in *Natural History* for March 1993, the scientist, educator, and writer Stephen Jay Gould explores topics in the domain of the sublime in biology and suggests "awesome grandeur" as a phrase fit for the present age. What do you think? You may want to take a draught of the Milky Way on a clear night or drop in at the Tate before answering.

Correspondence

Ice on Mercury

Sir, The report in ***Spaceflight*** (April 1993, p.139) on the possibility of ice caps on Mercury was very interesting. It seems that the polar regions of Mercury could be extremely cold. One wonders whether these polar regions might be surrounded by zones with relatively clement temperatures where astronauts might possibly land one day. However, even if this should not be so, it would be useful to send an orbiter to Mercury to study the properties of its surface and complete the mapping of the planet.

J.D.HUGHES
Liverpool, UK

An Indian Spacecraft to Mercury?

Sir, India has a comprehensive space research and applications programme, covering almost the entire range of activity except planetary missions and manned space flight. Should a recent proposal by the Indian Space Research Organisation (ISRO) win Government approval, India may launch a planetary spacecraft to study Mercury by the turn of the century. The detailed proposal was prepared by a team of leading Indian scientists headed by Dr K. Kasturirangan.

But why Mercury? It is pointed out that the planet has not attracted much study after the Mariner 10 fly-by mission. Neither have any plans been announced by any other space agency to that effect. Moreover, Mercury is a rather peculiar planet, with a 3:2 spin-orbit coupling and a high density of 5.45 g/cm^3, unusual for its small size, the report points out. Of particular interest are its gravity field, heat transport characteristics, interior, magnetism, seismicity, surface geological features, and the like.

A number of vital questions about Mercury remain unanswered. With only about half its surface covered by Mariner 10 pictures, a most obvious unknown factor concerns the surface features of the rest of that planet. In case these are very different, there may be a need for a reappraisal of our current views on Mercury. A better understanding of Mercury's surface composition and its differences with those of the other terrestrial planets is also worth a detailed study. Information on the core, whether solid or molten, as well as origins and detailed structure of the magnetic field are of interest. Additionally, does the magnetic field's intensity vary periodically, and does it reverse its polarity as does the Earth's field?

The proposed spacecraft, stabilised around three axes, would be of about 250 kg dry mass, and would be launched by a GSLV (Geosynchronous Satellite Launch Vehicle) currently under development into a 300 km circular parking orbit. From there, it would be further accelerated along a Venus fly-by trajectory, for a gravity assist to Mercury. Both fly-by and orbiter missions are being considered. According to the study, multiple swing-bys of Mercury would be required before insertion of the spacecraft into orbit around Mercury.

For the orbital mission, the spacecraft would carry a wide range of instruments. These would include particle detectors, plasma probes and a magnetometer for information on the solar wind and associated phenomena; an ultraviolet spectrometer to obtain the elemental composition of various gases, including the rare gases around the planet; a plasma analyser to measure solar wind particles in Mercury's transitional atmosphere; TV or high resolution (50-100 m) CCD cameras operating in a number of visible and IR bands; gamma ray, X-ray and IR spectrometers for surface material composition; IR and microwave radiometers to measure thermal emissions from the planet; and a magnetometer to map any magnetosphere that Mercury may have.

It may be mentioned that Indian satellites and their payloads have shown a remarkable level of reliability to date. Thus, India seems quite capable of designing and launching advanced spacecraft on prolonged planetary missions.

HORMUZ P. MAMA
India

NASA's Mistake

Sir, After having read the STS-53 mission report in the March issue of ***Spaceflight*** I found something very remarkable. You stated the different touchdown times (EST) as follows: main gear at 3:43:17 pm, nose gear at 3:44:04 pm, and wheels stop at 3:45 pm.

These times would theoretically* result in a rollout distance of approximately 5,140 m (16,863 ft) assuming a normal landing speed at main gear touchdown of 360 km/h (194 knots), not bad for the 15,000 ft long Runway 22.

I know that NASA stated these times in its MCC status report of December 9, 1992, but there is obviously something wrong. A normal Space Shuttle rollout just takes 60±15 seconds including 13±7 seconds for getting the nose gear down after main gear touchdown.

I heard the landing of STS-53 live on AFN (American Forces Network) Radio and can say that main gear touchdown occurred at 3:43:47 pm. (NASA's nose gear touchdown and wheels stop times are obviously right).

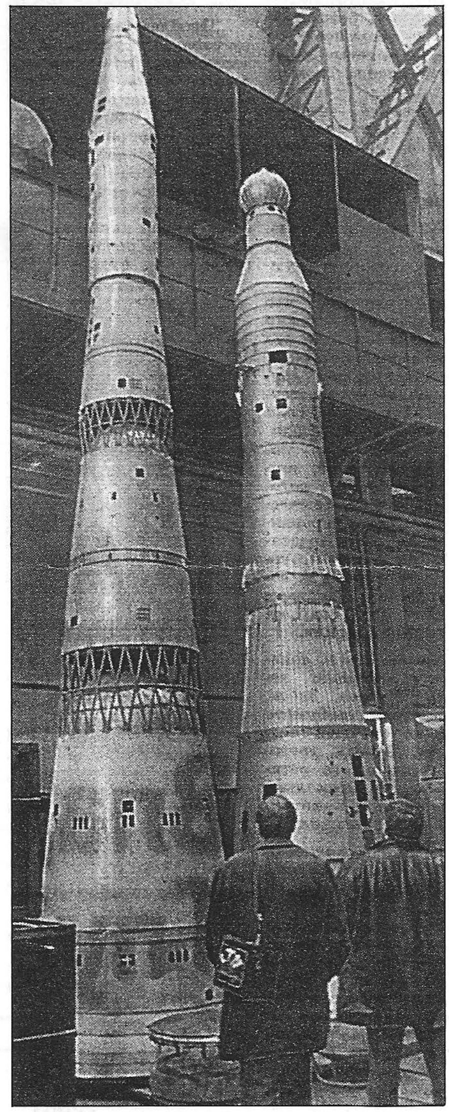
I know that this was NASA's mistake, but nevertheless please keep on publishing launch and landing times exactly to the second.

RALF HUPERTZ
Lennestadt, Germany

* Rollout distance = ½ (landing speed) x (rollout time).

The N-1 Rocket

Sir, I have found what I believe to be the proposed configuration of the N-1/L-3M, the proposed N-1 follow-on manned lunar project. The photograph below, published in the 27 March 1993 issue of the newspaper *Krasnaya Zvezda*, shows dynamic test models of two launchers.



The one in the foreground is the standard N-1 lunar launcher. The second model is clearly based on the N-1 (the first stage seems to be identical) but has completely new upper stages. The payload has an unusual "onion-dome" configuration that roughly matches that shown in a monograph titled "Why Didn't We Fly to the Moon?" by V.P. Mishin (published in English in the Joint Publication Research Service, JPRS-USP-91-006, 12 November 91).

It is difficult to tell whether the N-1/L-3M was to be a three- or four-stage launcher. Although the Russians have historically preferred a four-stage configuration, the illustration from the Mishin monograph indicates a fairly long final stage, which may be indicative of a three-stage launcher when matched against the dynamic test model.

MATTHEW FLAMMER
Virginia, USA

Mir Lunar Orbiter?

Sir, Professor Ruppe's dismissal (***Spaceflight***, April 1993, p.119) of Mr Parker's Mir Lunar Orbiter proposal (on p.56, February issue) seems unjustly harsh.

Undoubtedly the present Mir would be unsuitable due to its age but it is a tried and trusted design; Mir 2 is already under construction, so why not a Lunar Mir 3?

It is also hard to justify the professor's dismissal of SSME use of the Earth-Lunar orbit boost. An SSME has approximately 213 metric tonnes of thrust in a vacuum; taking the professor's all-up orbital weight of 180 t, this results in an orbit-leaving acceleration of 1.2 g; this hardly seems excessive.

Storage of cryogenic propellants for several days would indeed be a problem but it is my understanding that the Italian Space Agency as reported in *Flight International* is designing a LEO-GTO stage along the lines of the American Centaur which does exactly this, so the technology is probably already developed.

Besides, there is a positive flood of stages and motors that could do the job instead - either singly or in clusters - such as IUS or the Proton upper stages. Also contrary to Professor Ruppe's letter, there seems no need for the orbital transfer system to be man-rated; why not achieve the boost with the station unmanned?

His dismissal of Mr Parker's second "figure-of-eight" Earth-Moon loop proposal is also premature. Since refuelling of Mir's thrusters is routine [1] via Progress, maintenance of the loop's trajectory does not seem too troublesome. Perhaps the Freedom propulsion modules currently under test could be used here, since they would fit the bill (repeated firings over a long lifetime) admirably.

Progress or Soyuz could dock with the station through use of the Proton booster, i.e. rejuvenating the Zond project of the late 1960s. Here, Soyuz craft were launched on once-around figure-of-eight looping passages around the Moon!

Presumably such a manoeuvre would give the ferries sufficient ΔV for a rendezvous at some point on the station's figure-of-eight. This part of the project would be all the easier now we have twenty years plus experience of the Proton.

OLIVER de PEYER
Oxford, UK

Reference
1. Kenneth Gatland, "Encyclopedia of Space Technology", Salamander Books Ltd, 1989, p.196.

Soviet Launch Vehicle Classifications

Sir, In his letter published in the March 1993 issue of ***Spaceflight***, Maxim V. Tarasenko suggests that one of the launch vehicles he described may have been the missing 'E' class launch vehicle in Sheldon's designation system.

In a private conversation with Geoffrey Perry of the Kettering Group, who at the time worked with Sheldon on the US Congress publications, I was advised that Sheldon never intended to use the 'E' classification to avoid confusion with the meaning of 'e' for escape stage, which was used in the classification system.

For the same reason there is no 'H' class launcher; Sheldon used 'h' to designate a higher performance stage.

JOS HEYMAN
Western Australia

Sir, Tarasenko's statement about the 'E' class of the Sheldon system [1] is not correct. The late Dr Charles Sheldon devised his alpha-numeric classification of Soviet launch vehicles "In the absence of adequate Soviet names and descriptions, or even of a public Western nomenclature system" in 1968 [2]. He hypothesised six basic launch vehicles: A, B, C, D, F and G, with X used for the unknowns. The escape rocket would be labelled 'e'. That system stood the test of time for more than twenty years and is still in use today. I extended the system to include J for the SL-16 or Zenit and K for Energiya, 'h' having been used by Sheldon for a high-energy stage and to avoid possible confusion between 'l' and '1' [3].

Since the mid-80s, Western analysts have tended to use the de-classified US Department of Defense's SL-system solely or together with the Sheldon system. Now that *ITAR-TASS* launch announcements usually name the launch vehicle I suggest that the time has come to use those names, especially as we now have Start-1, the SS-25-derived commercial launch vehicle, and the promise of the launch of Radio-M, later this year, by a converted SS-19. The "missing" name, Tsiklon-M, for the F-1 (SS-9 Scarp or SL-11) launcher of FOBS, RORSATs and EORSATs appeared only recently [4]. This leaves just one area of confusion - the use of the same name, Cosmos, for both of Sheldon's B-1 (SL-7) and C-1 (SL-8) launch vehicles.

G.E. PERRY MBE FBIS
Cornwall, UK

References
1. Maxim V. Tarasenko, "Soviet Launch Vehicle Classifications", ***Spaceflight***, March 1993, p.108.
2. Charles S. Sheldon II, "The Soviet Space Program: A Growing Enterprise", TRW Space Log, no. 4, Winter 1968-69, pp.2-23.
3. Soviet Space Programs: 1981-87, Part 1, US Government Printing Office, Washington, May 1988, ch. 3, pp.229-256.
4. ITAR-TASS new agency, Moscow, World Service in Russian, 0618 GMT, 3 April 1993.

US Aerospace Plane Efforts

Sir, The fine article by Doug Millard on "Spaceplanes - Back to the Future", page 74, in the March 1993 issue of ***Spaceflight***, is a little bit overly brief with its history of United States efforts in the 1958-1964 era. Those years were characterised by intensive Aerospace Plane efforts by many US contractors. In 1993 dollars, very roughly about 1 billion US dollars were spent, and many hardware developments were pursued. Spurred by stated needs for "routine access to space" and incorporating operatoinal features still common to modern (1993) programmes, a large number of concepts was investigated in depth.

Consistent with these needs and operational features, this early US Aerospace Plane programme considered a great many vehicle configurations. After reviewing and dismissing several options still considered "exotic" today (such as use of an electrical accelerator), the more attractive remaining options extensively studied included:

1. Single-stage-to-orbit (SSTO) using air enrichment and collection, and employing chemical rockets as the final propulsion mode.
2. SSTO using a nuclear rocket as the final propulsion mode (variants using nuclear air-breathing engines were also contemplated).
3. SSTO using a supersonic combustion ramjet (i.e. a scramjet) as the final propulsion mode.
4. Two-stage-to-orbit (TSTO) using air enrichment and collection technology, and a conventional chemical rocket for second-stage propulsion.
5. TSTO, using air-breathing propulsion for the first stage (all propellants carried on board from takeoff), with conventional chemical rocket propulsion for the second stage.
6. Same as 5, except that a nuclear rocket second stage was considered.
7. TSTO carrying all propellants on board from takeoff and using scramjets to power the second stage.
8. Use of various modes of hypersonic modes of hypersonic inflight refuelling systems (HIRES) and employing a conventional chemical rocket as the final propulsion stage (one- and two-stage versions are possible).

It is of some interest to note that of these options one can say:

- ❑ The recent US NASP programme resembles Option 3, with the proviso that final orbit injection with chemical rockets (à la Option 1) was finally deemed necessary.
- ❑ The German Sänger programme is essentially Option 5.
- ❑ Hotol variants of several kinds are also found in this list of options (e.g. Option 1).

In their final review of options in the 1963-1964 period, the United States Air Force selected for possible development "first generation" options (the TSTO variants), and of these then highlighted Option 5 as the final development candidate. The programme was terminated shortly thereafter, for a combination of reasons, including cost, ambiguity of real requirements, and technology closure issues. The scope and depth of the Aerospace Plane work done during the 1958-1964 era is still underappreciated, even in the United States, and the effort as a whole is not adequately documented.

BRUNO W. AUGENSTEIN
Senior Scientist, RAND
California, USA

Timberwind

Sir, I am just writing to say how much I enjoyed the March issue of ***Spaceflight*** and in particular Paul Blase's article on the "Delta Clipper" project. We may hope it will not follow the path to the budget cut oblivion of its illustrious predecessors!

Mr Blase makes passing reference (last paragraph, page 92) to "the recently announced Timberwind nuclear rocket". Is any further information available on this project? Is it similar to the NERVA nuclear engine project cancelled by the US some years ago?

PAUL McKINLEY
Dublin

In response, Paul Blase writes:
There have been several articles on Timberwind in *Aviation Week and Space Technology* particularly in the issues of January 7, March 18, April 8 and December 2 of 1991. Timberwind is a particle-bed reactor nuclear engine based on the 1960s NERVA engines. So far as I know, it is still a conceptual design, no working hardware has yet been built.

Lunar Exploration

Sir, I like the survey by Heinz-Hermann Koelle beginning on p.48 of the February issue of ***Spaceflight*** very much. Unfortunately, if development costs were included Fig. 2 may well be increased by a factor of 30 and Fig. 3 by a factor of 20. It is well known by now that reusability of the large launch vehicle may turn out to be a cost driver, not a cost saver. No doubt this would effect conclusions severely.

Prof Dr-Ing HARRY O. RUPPE
Munich, Germany

Competition

Answer these simple questions and win a video prize!!

Lunar Base Competition

(Please print or type)

Study the sketch on the opposite page of a Lunar Base and identify by number (using Nos. 1 to 9):

A. The solar power system for the outpost ____________

B. A thermal radiator for disposing of excess heat ____________

C. What is being used to provide protection from radiation from space ____

D. A permanent habitat ____________

E. An equipment and supplies store ____________

Complete the following two sentences as you consider most appropriate:

(1) The road marked (10) leads to ____________

(2) The solar power collector (11) provides energy for the manufacture of __

____

Those entries that offer the greatest number of correct (or appropriate) answers will be entered for a prize-winning draw.

Complete this form and post it to arrive by first delivery on 3 June 1993.

Return to: The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Title/Name ....

Address ....

....

....

BOOK NOTICES

These notices, compiled by L.J. Carter, are not intended to be reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

Full publication details are given for each book to enable copies to be ordered from a local bookseller, if desired. The address of each publisher also appears, for many items can now be ordered direct from them. If not, they will supply the address of a local agent who can handle matters.

The Navstar Global Positioning System

T. Logsdon, Van Nostrand Reinhold, 115 Fifth Avenue, New York, NY 10003, USA, 1992, 256pp, $44.95.

This mathematics-free book provides a valuable insight into the unique Navstar Global Positioning System for both specialists and non-specialists alike. Navstar is a space-based radio navigation system which enables an unlimited number of users to receive, passively, details of their longitude, latitude and altitude. The book not only explains what the Navstar GPS is, how it operates and how it compares with other space-based systems, but illustrates how to use it more effectively to ascertain one's position, velocity and the exact time.

Navstar GPS is now being applied internationally for a range of uses including air traffic control, geodetic surveying, offshore oil exploration, automotive and railroad navigation and archaeology. It also has a number of military uses.

The book also digs into a number of new areas, such as differential navigation, including the applications and benefits of pseudosatellites, and integrated navigation - including coverage of ring laser and fibre optics gyros. It details experimental work currently being undertaken to expand still further the many applications of the system.

Giotto to the Comets

N. Calder, Central Books, 99 Wallis Road, London, E9 5LN, 223pp, 1992, £8.95.

On 10th July 1992 ESA's spacecraft, Giotto, battered but still functional after its historic encounter with Halley's Comet, flew through Comet Grigg-Skjellerup as the culmination of a seven-year odyssey.

This book describes the double cometary mission, drawing on interviews with those who accomplished it in the face of often daunting difficulties.

It also explains why comets are prime objects of study for anyone who wishes to learn more about the evolution of our world for, now that we know what a comet nucleus looks like and what it is made of, provocative new questions have emerged about the influence of comets on the Earth, its atmosphere, oceans and biosphere.

Binaries as Tracers of Stellar Formation

A. Duguennoy and M. Mayor, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1992, 292pp, £35.

With more than two thirds of the stars in the sky already members of multiple systems, binary stars are now considered as one of the best constraints on stellar formation models. Not only do they retain evidence of their birth conditions but their orbits are also subject to changes from such things as tidal effects, wind accretion and encounters in clusters, a correlation between orbital eccentricity and orbital period thus providing a clue to understanding double star history.

For the first time, detailed orbital elements are available for stars of differing masses, ages and metallicities, so making it possible to search for traces of stellar formation among statistical properties.

The 20 or so contributors to these proceedings discuss the most recent observations with the aim of disentangling evidence of stellar formation from subsequent physical evolution, reporting on the physical processes taking place after stellar formation which may have altered the primordial properties of the binaries which cover such a wide variety of the stellar population.

The Great Copernicus Chase

O. Gingerich, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1992, 304pp, £19.95.

This volume reprints accounts of many of the astronomical excursions conducted by the author originally described in *Sky and Telescope* and similar periodicals.

They explore a great spectrum of topics, as wide ranging as the origin of the Zodiac, the secret of detecting fake astrolabes, how optical astronomers beat radio astronomers in the race to discover the spiral arms of our Milky Way, and more.

The author's adventures into the history of astronomy are based on a passionate personal interest. The result is an anthology of astronomical anecdotes, discoveries and controversies. All the important developments are covered, starting with the ancient Egyptians and embracing the Greek and medieval scholars. The book's title comes from the author's own individual project, *viz* ascertaining how many copies of *De Revolutionibus* by Copernicus were originally printed, how many have survived and where they can be found.

A Tapestry of Orbits

D. King-Hele, Cambridge University Press, The Edinburgh Building, Cambridge CB2 2RU, 1992, 244pp, £35.

Satellites crossing the sky look like moving stars. Their paths can be accurately tracked by an observer using binoculars as well as by radar and giant cameras. Such observations are used to determine the satellite's orbit, which is sensitive to drag exerted by the upper atmosphere, as well as to irregularities in the Earth's gravitation field. Analysing the orbit can thus help to evaluate the density of the upper atmosphere and define the shape of the Earth.

The author, who has made his name by his work on orbit analysis, describes how this work began, even before the first Sputnik launch in 1957. For thirty years he developed and applied the techniques which revealed much about the Earth and its upper atmosphere at very modest cost. In the 1960s the density of the upper atmosphere was mapped out for heights between 100 and 2000 km, revealing great changes in density between day and night and also due to Sun activity. In the 1970s and 1980s a picture of the upper atmosphere winds emerged and a profile of a slightly pear-shaped Earth was ascertained.

This book, which abounds with personal experiences, recounts how all this work was developed to yield such a rich harvest.

New Astronomy

Johannes Kepler, Trans. by W.H. Donahue, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1992, 665pp, £85.

Kepler's "New Astronomy" *(Astronomia Nova)* as it is now commonly called, was published in 1609 and is one of the four greatest astronomical treatises ever written. It swept aside the deductive geometrical approach to astronomy which had been used from ancient times and rejected the uniform circular motions which had previously been thought indispensable.

In no less than 70 chapters and with title-page originally reading "The commentaries on the motion of the star Mars", Kepler made a bold attempt to use physical theory and accurate obser-

vation to establish the actual shape of the orbit of Mars, an approach quite unlike anything that had been tried before. He thus tested the ancient hypotheses, found them wanting and replaced them with what we now recognise as fundamental physical theory. His discovery of elliptical planetary orbits was a crucial step which laid the foundation for the development of classical physics later in the 17th century.

This is the first time a complete translation has appeared in English. The layout and design of Kepler's original edition has been retained, wherever possible, and a glossary added to define technical and unusual terms, together with Latin expressions which have no exact English equivalents.

Space Robotics: Dynamics and Control

Eds: Yangsheng Xu and Takeo Kanade, Kluwer Acedemic Publishers Group, P O Box 989, 3300 AZ Dordrecht, The Netherlands, 1992, 284pp, £54.50.

Robotic technology promises two major benefits for future space exploration. One lies in minimising the risks which astronauts need to face: the other is in increasing their productivity. However, benefits from robotic technology in space first require solving a number of problems, practically all of which are currently active areas of research. One of the most important of these areas comprises the dynamics, control, motion and planning of space robots and the dynamic interaction between the robot and its base, i.e. a space station, space shuttle or satellite, where any inefficiency in planning and control can put success of the mission to considerable risk.

This volume presents ten papers which are concerned with solving these fundamental problems in the dynamics and control of space robots and focuses, particularly on issues relating to the dynamics base/robot interaction. Chapters are organised into three major areas - dynamics problems, nonholonomic nature problems and control problems.

As all of the authors are pioneers in the development of theoretical analysis and experimental systems required by space robot technology, the collection provides a solid reference base for further research.

Planet Earth: Cosmology, Geology and the Evolution of Life and Environment

C. Emiliani, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1992, £55 (Hardback), £19.95 (Paperback).

Man is likely to witness an increasing number of deep environmental crises over the next few decades and he will be able to cope with such matters only if he has a clear understanding of the complex and delicate biosphere of which we all form part.

Our planet is at risk. The current explosion in the human population is forcing us into a simple but vital choice viz: either to stabilise the planet or perish. It is only by achieving a close understanding of the system of which we form part that we will be able to cope with these enormous problems.

Fortunately, the great advances being made in all fields of science are making it possible, for the first time ever, to reconstruct the entire life history of our world from the "big bang" to today, thus providing an understanding of how the system works.

This book presents a global picture of our world: how it originated, how it evolved and how it functions and provides much of the background needed to help us to assess ways in which we may hope to stabilise conditions.

Although the scientific background provided is both rigorous and quantitative, the book is written in an informal style and readily accessible to anyone with a knowledge of algebra. It is particularly recommended to science teachers to help with lessons designed to show how a better understanding of various arenas of science can be integrated into one complete whole. It is a book which gives rise to concern yet provides much of hope.

Angle of Attack: Harrison Storms and the Race to the Moon

M. Gray, J Wiley & Son, W.W. Norton & Co Ltd., 10 Coptic Street, London, WC1A 1PU, 1993, 304pp, £16.50.

In the political storm that followed the early Soviet Sputnik launchings, Harrison Storms, the chief engineer of North American Aviation, was called upon to build the Apollo spacecraft, a challenge of a new and frightening order for Apollo was one of the most ambitious engineering projects ever undertaken by man. It involved building a rocket 36 storeys high loaded with explosives equivalent to a nuclear device, with men then placed on the top and then launched to the Moon, a task undoubtedly more complicated than the Manhattan Project and the Panama Canal combined.

Storms and his engineers had to feel their way along an almost uncharted path, while changing orders from NASA caused the ship's design to be constantly altered.

It recounts the triumphant American achievement in a book which describes the story of some 400,000 men and women, altogether, who combined their talents to build the first spaceship to leave Earth.

Solar System Evolution: A New Perspective

S.R. Taylor, Cambridge University Press, The Edinburgh Building, Cambridge, CB2 2RU, 1993, 307pp, £35.00.

This interesting book describes the origin and evolution of the solar system with an emphasis on interpretation rather than on description. Starting with the Big Bang, some 15-20 billion years ago, it traces the evolution of the solar system from the separation of the initial disc of gas and dust, *viz*: the solar nebula, some 4.7 billion years ago.

Problems with the formation of the Sun and planets are considered, beginning with Jupiter and the other gas giants and ending with the formation of the Earth, the other rocky inner planets and the Moon.

The conclusion is that all planets, satellites and rings are different and that random encounters must have played a major role in the evolution of the system.

A prologue emphasises that, despite the enormous wealth of new data about the solar system, little has been ascertained about its origin until quite recently. This underlines the crucial role of further lunar exploration. An Epilogue considers the place of man in the solar system from which the author concludes that so many chance events have occurred that the solar system is probably unique. Other planetary systems may be common, but the chances of finding a replica of our own seem remote.

The Concept of the Universe as Perceived Throughout the Centuries

Henri-Louis Andrillat, Masson, 120 Boulevard Saint-Germain 75280 Paris, Cedex 06, France, 1992, 280pp, 220FF.

Subtitled "Modern Theoretical Cosmology and its Origins", this book analyses the various concepts of the creation, structure and evolution of the universe as envisaged from ancient to modern times.

The origins of the current models of an expanding universe emanating from the "Big Bang" theory are examined in detail. Various landmarks include the General Relativity Theory which led to the concept of the curvature of space, the work of Robertson in which the expanding Universe concept enabled Hubble's Law to be understood, the work of Friedman undertaking the initial "Big Bang" and, finally, the most complex and puzzling aspect of modern physics, the grand unified theory involving the four fundamental physical forces.

All these theories are presented and accompanied by brief mathematical and observational data, in particular that recently obtained from the Cosmic Background Explorer (COBE) launched in 1989 to study background radiation, especially from extremely early sources.

This book provides students, instructors and advanced amateurs with the essential aspects of the major cosmological theories together with the necessary documentary references.

Solar Power Satellites: The Emerging Energy Option

Eds: P.E. Glaser, F.P. Davidson and K.I. Csigi, Simon & Schuster International Group, Campus 400, Maylands Avenue, Hemel Hempstead, Hertfordshire, HP2 7EZ, 1993, 300pp, £62.50.

A major problem which will undoubtedly affect mankind in the 21st century will be the reduced available energy resources, so finding new reserves, particularly those suitable for large-scale collection and distribution will be of major importance. Solar energy is the logical natural resource which meets these needs but it can only be achieved as a result of an international consensus, particularly as the exponential population growth will lead to the possible doubling of the world's population by the middle of the 21st century. There is a correlation between population growth, life expectancy and energy consumption.

Solar power satellites are emerging as an environmentally-friendly energy option which will help mankind to meet his future energy requirements. Prepared by an international team of contributors, this is a book which provides a comprehensive review of the current state of the art in this rapidly developing area and sets out a framework to enable the right steps to be taken to lessen our current dependence on non-renewable resources. It looks at how to mitigate possible global warming and ecological degradation by addressing many of the technical, economic and social issues involved.

Beyond Southern Skies: Radio Astronomy and the Parkes Telescope

P. Robertson, Cambridge University Press, the Edinburgh Building, Cambridge, CB2 2RU, 1993, 357pp, £40.00.

This volume recounts the story of the planning and construction of the Parkes Telescope in New South Wales, Australia and surveys its achievements over the past 30 years.

A subordinate historical theme is the rapid rise of radio astronomy in Australia from its origins in the secret radar research carried out during World War II by CISRO's Radio Physics Laboratory in Sydney. After the war, radio astronomy centres emerged in the UK, the Netherlands and in the United States but the radio physics group "down under" grew to be the largest and most diversified of them all and, perhaps, the most successful.

A fascinating and lively account is included of the personalities, the politics and the controversies that lay behind the decision to build the Telescope.

The Official Opening on 31 October 1961 marked a special day for science and Australia, with the culmination of an idea first conceived ten years earlier and a Telescope which had taken four years to design and two years to construct.

SOCIETY MEETINGS DIARY

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.

It may occasionally happen that, for reasons outside its control, the Society has to change the dates or topics of meetings. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always recheck the scheduled meetings in the latest issue.

14 August 1993

48th Annual General Meeting

The 48th Annual General Meeting of the Society will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, on Saturday, August 14, 1993 at 12 noon. Details of the Agenda will be published in due course.

Admission is by ticket, available to Corporate Members (i.e. Fellows of the Society) only, who should apply in good time enclosing a stamped addressed envelope.

Council nomination forms are obtainable from the Executive Secretary. These must be completed and returned not later than 12 noon on May 22, 1993. If the number of nominations exceeds the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all Corporate Members.

6 October 1993 7 pm - 8.30 pm

Microsatellites on Micro-budgets

Prof. M. N. Sweeting

The prohibitively high cost of space projects has effectively restricted first-hand access to space to a handful of nations and international agencies. Spacecraft have grown ever larger and more complex and are also taking longer time-scales from concept to orbital operation. Advances in VLSI micro-electronics have catalysed a new species of small, low-cost yet sophisticated and highly capable 'microsatellites' - complementing, and sometimes providing an alternative to, high-cost traditional satellites.

The lecture describes the University of Surrey UoSAT microsatellite programme which reviews the key technologies, management techniques and potential applications of small satellites.

SYMPOSIA & CONFERENCES

12 June 1993 10 am - 4.30 pm

Soviet Astronautics

The symposium is in its 13th year as an event which reviews the space programme of the former Soviet Union. The programme for 1993 will include talks on the following topics: The Biosputnik programme up to 1993; USA-Russian Manned Cooperation 1992-1995: update on the Manned Operations on Mir; Obscure Unmanned Soviet Satellite Missions, and others still to be decided. A Film will be shown including clips never seen before in the UK. There will be opportunities to ask questions of some of the leading experts on the Soviet Space Programme in the West.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Advance Registration is necessary.

Registration: Forms are available from the Executive Secretary. Please enclose a sae.

22 September 1993 10 am - 4.30 pm

European Rocketry in the 1930's

As part of the Society's Anniversary Year the History Working Group are holding a Symposium on European Rocketry in the 30's. Contributions have been invited from Germany, France, Russia and the UK. The 30's is seen as a particularly interesting decade in that much theoretical and practical work was undertaken that laid solid foundations for later projects.

Whilst much publicity has surrounded the experimental and theoretical work carried out in Germany an enormous amount was also carried out elsewhere, particularly in Russia. Much of this story has yet to be told.

Advance Registration is necessary.

Registration: Forms are available from the Executive Secretary. Please enclose a sae.

15 - 17 October 1993

SPACE '93: Space Initiatives

This Special Society two-day meeting to commemorate the Society's Diamond Jubilee, 1933 - 1993 will include themes on:

- Overviews
- Exploring the Planets and Beyond
- Space for the Benefit of Mankind
- New Space Concepts
- Ways and Means

For more information see Society News on p.202. A special rate for the weekend has been negotiated with two hotels.

Advance Registration is necessary.

Details of the Programme, Registration Forms and Hotel Accommodation are available from the Executive Secretary. Please enclose a sae.

16 - 22 October 1993

44th International Astronautical Congress

The 44th International Astronautical Congress will be held in Graz, Austria, from October 16 - 22, 1993 under the auspices of the International Astronautical Federation (IAF) and its associated bodies, the International Academy of Astronautics (IAA) and the International Institute of Space Law (IISL).

The Congress will be held at the Grazer Congress (Convention Center Graz). This is an excellent facility, centrally situated in the heart of the old town.

Hotel rooms have been reserved at special rates for Congress participants and guests.

Details of the Programme, Registration Forms, etc. will be available from BIS HQ shortly.

LIBRARY

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. The Library will also be open on Saturdays between 10.00 am and 1.30 pm on the following dates:

21 August
18 September
23 October
20 November
18 December

Membership cards must be produced.

INTO THE NEXT MILLENNIUM

An invitation to:

"SHARE OUR IDEAS FOR THE FURTHER EXPLOITATION OF SPACE, THE DEVELOPMENT OF TECHNOLOGY AND OF THE SOCIETY ITSELF"

Does the above look or sound familiar? The avid reader will recognise the words of Mr Martin Fry as detailed in Society News, November 1992.

So why repeat them here? Well Martin went on to say:

"WE INVITE ALL TO SHARE WITH US IDEAS AND TO CONTRIBUTE TO THEIR REALISATION IN THE YEARS AHEAD."

Thus the Society needs your involvement in meeting this challenge. A Council Advisory Committee on Space Policy and Technology has been formed in this the 60th year of the Society to develop short, medium and long-term plans for the Council to use as blueprints for its strategy in addressing Space Policy and Technology Exploitation.

Martin Fry, as chairman of the committee would welcome your thoughts and proposals for the consideration in the committee. The committee will undertake to evaluate all concepts proposed and critically assess their suitability. In making your submission to the Society known to Martin please assist the committee by detailing the commitments that you can provide in developing the proposals further.

So if you wish to contribute in assisting the committee with its task please write to Martin Fry care of the Society Headquarters.

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JOIN THE BRITISH INTERPLANETARY SOCIETY

When you join the British Interplanetary Society *Spaceflight* will be mailed directly to your home address each month, hot off the press.

As a member of the Society you will become part of a worldwide organisation which promotes space and astronautics and be able to attend the wide range of Society meetings, visits and other special events. Members also receive discounts on Society publications and entry to symposia.

This offer includes either a FREE official Society pin-on lapel badge *or* a voucher that entitles you to £5 OFF any title in the BIS Video Collection.

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I enclose (a) £35 (US$70) for a 12 month subscription from January-December 1993 ☐
(b) £52.50 (US$105) for an 18 month subscription from July 1993 to December 1994 ☐

Special reduced rates are available for those under 22 or over 65 years. For (a) the amount is £26 (US$52). For (b) the amount is £39 (US$78)

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Signature Date	*Application constitutes acceptance of the Society's Constitutional Rules*

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Spaceflight

The International Magazine of Space and Astronautics

Behind the Soviet Space Curtain

Manned Lunar Programme
Space Plans and the CIA
Mars Missions

Project SPACEGUARD:
The Fiction and the Fact
By Duncan Steel

- SHUTTLE: European Experiments on German Spacelab
- LAUNCH REPORT: Preparations and Recent Launches
- ASTRONAUTS: Europeans Selected for 'Mir' Flights
- 'LUNAR BASE' COMPETITION WINNERS

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The BIS Video Collection

The BIS is proud to offer a stunning record of man's exploration of space brought to your home on video.
All videos are extracted from original footage.

Apollo 8: Go For TLI

This Saturn V flight was man's first journey around the Moon and forerunner of the Apollo lunar-landing flights. The three-man crew (Borman, Lovell and Anders) set course for the Moon, passed behind it and transferred to a lunar orbit, circling the Moon ten times in 20 hours. Their many still photographs and much cine film helped to decide on landing sites for later missions. The final TV transmission took place while 97,000 miles from Earth. *22 mins*

Apollo 9: Three to Make Ready

Building on the successful flight of Apollo 8, a lunar module was tested in space, as was the life support system of the space suit. Two of the three-man crew (McDivitt, Scott and Schweickart), transferred to the Lunar Module, moved 100 miles away from the Command Module and then returned to rendezvous with it. The two men then transferred back to the Command Module and the Lunar Module was jettisoned. *17 mins*

Apollo 10: To Sort out the Unknowns

Lift-off to a trans-lunar orbit by Stafford, Young and Cernon, with views of Earth and system checks *en route*. There was loss of communications signal while passing behind the Moon as the craft transferred to lunar orbit. Signal acquisition returned when the spacecraft reappeared, with TV pictures showing the Lunar Excursion Module (LEM) undocked from the Command Module and descending to within 50,000 feet of the lunar surface. Direct communications between Control and LEM failed so access was made *via* the CM. LEM subsequently rendezvoused with the CM, the crew transferred again and LEM was jettisoned. *26 mins*

STS-49 Mission Highlights

The details of this flight by the Shuttle Endeavour, 7-16 May, 1992, are well covered, e.g. the preliminaries of suiting-up, the White Room, entry to orbiter, removal of gantry, count-down, engines start, lift-off, and detailed operations during the flight. A principal aim was to retrieve the Intelsat VI satellite which had previously failed to reach synchronous orbit. Though more difficult than expected, it was achieved and sent on its way. A second aim was to practice basic space station assembly work by Extra-Vehicular Activity (EVA). This was also very successful. The video concludes with an interesting press interview with the crew. *1hr 50 mins*

Mission of Apollo Soyuz

In July 1975 spacecraft from the Soviet Union and the United States blasted off on an historic mission. Two days after blasting off Apollo and Soyuz docked high above the Atlantic Ocean. This NASA film covers the scientific and technological achievements of the mission and stresses the spirit of cooperation and friendship. *28.5 mins*

Time of Apollo

In 1961, President John F. Kennedy set forth the task... "This nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth". This film is a tribute to the historical accomplishments of the Apollo programme. *29 mins*

Skylab: The First 40 Days

Records the launch of the unmanned Skylab 1, the major problems that followed and the repair during the manned Skylab 2 mission. Includes on-board sequences of daily work routines and some of the experiments. *22.5 mins*

Skylab: The Second Manned Mission

Covers the Skylab launch activities and docking with the orbital workshop. Includes observations of student experiments, crew medical experiments, exercise routines and the activation of the Earth Resources Experiments Package. *36.5 mins*

The World Was There

This NASA film, using original footage from the sixties, shows how the news media of the World covered the manned space launches of NASA's project Mercury. *27.5 mins*

STS-49 Post-Flight Crew Press Conference

Shuttle flight STS-49 proved to be the most dramatic mission in the 11-year history of the programme. Endeavour, on its maiden flight, had to chase the Intelsat-6 satellite three times. The first two attempts to capture the satellite ended in failure. On the third and, finally successful attempt, it took a record-braking three spacewalkers to grab the slowly spinning satellite. In this NASA production the STS-49 crew describe their daring mission. *22 mins*

Please send me the following cassette(s): Please Tick

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❑ The Eagle has Landed: The Flight of Apollo 11	£11 (US$22)
❑ Apollo 13: "Houston... We've got a problem"	£11 (US$22)
❑ Apollo 15: In the Mountains of the Moon	£11 (US$22)
❑ Apollo 17: On the Shoulders of Giants	£11 (US$22)
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❑ The Apollo Collection (Apollo 11 - 17)	£60 (US$120)
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❑ Gemini X Quick Look & Gemini XI	£11 (US$22)
❑ The Gemini Collection (5 videos)	£45 (US$90)
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❑ Space Shuttle Challenger: Accident Investigation	£11 (US$22)
❑ STS-49 Mission Highlights	£18.50 (US$37)

For a full list of BIS video cassettes please send a SAE to the address below.
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Spaceflight

The International Magazine of Space and Astronautics

Published By The British Interplanetary Society

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Front Cover: The Soviet Mars-1 probe that was launched on 1 November 1962 on a flyby mission to Mars.
Codr

Project SPACEGUARD: The

In 1973 Arthur C. Clarke published his novel *Rendezvous with Rama,* the first chapter of which was entitled *SPACEGUARD.* This took its name from a fictional programme invented by Clarke in which mankind mounted an interplanetary surveillance programme, searching for asteroids and comets on an impact course with the Earth. Now, astronomers and space scientists world-wide are joining forces to try to mount just such a programme, turning the fiction into fact. The name selected for the programme? *SPACEGUARD,* of course.

BY DUNCAN STEEL
Australia

No-one who reads the popular press could have missed the excitement (and concern) which has been engendered over the past few years by discoveries of asteroids passing close by the Earth (astronomically-speaking). At the time of writing, the record is held by 1991 BA which missed us by less than half of the lunar distance in January 1991: despite its small size (5 to 10 m across and the smallest and intrinsically faintest natural object ever observed telescopically above the atmosphere, although it has since been equalled) 1991 BA would have caused an airburst with an energy of the order of 50 kilotonnes of TNT (four times the Hiroshima bomb) if it had struck the planet.

In fact the 'annual event' upon the Earth due to extraterrestrial impacts, usually resulting in an atmospheric detonation largely-unnoticed on the ground, is a $\sim$ 20 kilotonne explosion [1]. Larger objects, such as the 50-60 m body which detonated above the Tunguska River region of Siberia on 30 June 1908 in an explosion with a total energy release of about 20 megatonnes of TNT equivalent, arrive on a time-scale of centuries, at the outside.

I have recently suggested, partially on the basis of Maori mythology, than an event similar to Tunguska may have occurred over southern New Zealand about 800 years ago, and there is a similar myth amongst the aboriginal people of western New South Wales. This relates the story of a foretold falling star bringing fire and havoc as it shot through the skies, killing many people and depositing strange stones: sounds like a large meteorite impact to me. There are indeed more recent tales of peculiar rocks falling from the sky bringing strange fires (for example, a meteorite fall in Zaïre in 1929 which caused a small fire has recently been documented). In fact, British astrophysicists Victor Clube and Bill Napier [2] have shown that such myths are common features of many civilisations, and with Mark Bailey [3] they have shown that there is evidence in the scientific records (for example, Chinese and Japanese fireball/meteor shower observations over the past two millennia) to suggest that the mythology may be a reasonable record of variations in the terrestrial influx.

Along with Clube, Napier and Bailey, I believe that the influx of large bodies to the Earth may not be random in time, but rather episodic, with the influx over the past 10-20,000 years being higher than the long-term average, due to the break-up of a large comet in an Earth-crossing orbit over that time. We believe that intersections of the debris from that break-up with the Earth lead to distinct episodes every few centuries in which the meteoroidal influx is enhanced, significantly affecting the terrestrial climate.

However, in the present context I will step back from my own detailed views and rather give an account of the majority-held belief amongst scientists working in this area: that the Earth is struck a cataclysmic blow every so often, and randomly in time, and this can affect all manner of things including the geological face of the planet, the environment, and of course the fauna and flora. Ample evidence for mass extinctions exist in the palaeontological record. It is generally agreed that the threshold for global effects by a single impact, dependent upon velocity and composition, lies somewhere in the region of 1 to 2 km. The mean impact rate by such objects, producing craters of the order of 10-20 km across, is about one per 100 to 300 thousand years. However, the frequency of smaller impacts, for instance those capable of wiping out life on a national or continental scale, is rather higher. Just how high, we do not know at this stage since few small (10-250 metre) Earth-crossing asteroids are known, and indeed we only know of an estimated 1-2% of the more massive Earth-crossers since there may well be several thousand larger than 1 km in size.

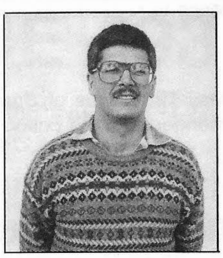
The History of the Mega-Impact Concept

As our knowledge of the population of macroscopic objects crossing the terrestrial orbit has increased over the past couple of decades, it has become clear that our planetary home is subject to large impacts, with potentially catastrophic consequences for our species, with a disturbing frequency. This paradigm shift, whereby astronomers no longer look at the pockmarked surface of the Moon and fondly believe that for some reason the Earth escaped such cratering, has also led to an alteration in the view of many geologists, many now recognising that impacts by asteroids and comets have in the past played a pivotal role in shaping the surface of this planet as well as the faces of other planets and their satellites: and indeed they continue to do so. How has this situation - the paradigm shift - come about?

The first Apollo-type (Earth-crossing) asteroid was discovered in 1932. Prior to this there were several comets known with Earth-crossing orbits (for example, Comet Halley: Sir Edmund Halley himself pointed out that this meant that catastrophic impacts were possible, if not inevitable) but these are much easier to spot than asteroids so that it was known that the cometary population could not be large. However, the discovery of three Apollos in the 1930s, with untold numbers unseen, meant that the Earth was perhaps not so safe a domicile as had been previously thought. At least a few scientists recognised this, notably Fletcher Watson [4] and Ralph Baldwin [5], but the majority thought little of it, leading to the rapid paradigm shift which has occurred over the past decade being delayed for many years.

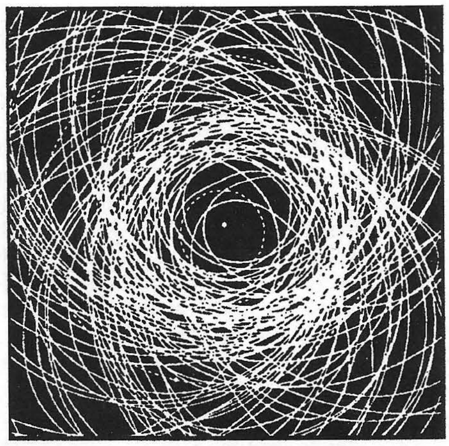
It is interesting to note that the word 'disaster' actually means 'bad star'; and obviously any comet or asteroid striking us would be very bad news indeed, at least in the present epoch. In the earlier history of our planet we should be pleased that many impacts occurred since these apparently sup-

About the Author



Dr Duncan Steel is a research astronomer at the Anglo-Australian Observatory in Coonabarabran, NSW, and at the University of Adelaide, South Australia. In 1991-92 he served on the NASA Workshops on the Detection, and the Interception and Diversion, of Near-Earth Objects, and is currently a member of the International Astronomical Union Working Group on Near-Earth Objects, and the Board of Trustees of the International Institute for the Asteroid Hazard in St Petersburg, Russia. This article is based upon a talk he gave in July 1992 at the Minehead Space Age Festival, celebrating Arthur C. Clarke's birth in that town 75 years ago. Like Clarke, Steel is a native of Somerset, England.

Fiction and the Fact



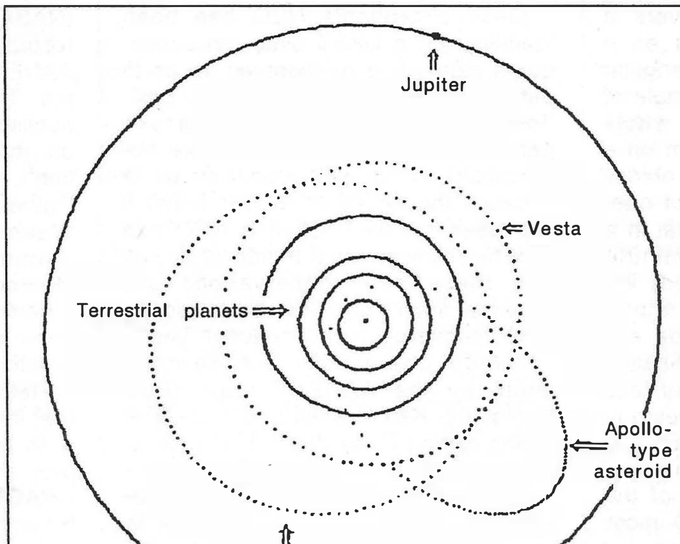
The orbits of the largest 100 known near-Earth asteroids, superimposed on the orbits of the terrestrial planets. The dot at the centre shows the position of the Sun, the innermost dashed ellipse is the orbit of Mercury, whilst the outermost one is that of Mars. The orbits of Venus and the Earth are just discernable in the most densely populated region of the diagram.
Courtesy Professor R.P. Binzel, Massachussetts Institute of Technology

plied the globe's repository of water and other organics. Nor is the past contribution of materials to the planet by asteroids and comets, and the extinction of the dinosaurs leading to the rise of the mammals, the only ways in which these may be beneficial to mankind: in the future we may anticipate that near-Earth objects (NEOs: asteroids and comets) will be a major source of raw materials for the exploitation of space.

Returning to the mention of dinosaurs, it is largely due to them that the asteroid impact idea gained scientific currency. Just why these beasts died out about 65-66 million years ago, having ruled the planet for aeons, has been a problem for well over a century. In 1980 Nobel prizewinner Louis Alvarez and co-workers published a paper showing that the geological stratum at the time of the dinosaur mass extinction bears a large quantity of iridium and other rare metals: rare on Earth, but more common in meteorites. This they suggested originated in a huge (10 km) asteroid which plummeted into our planet, the catastrophic effect upon the environment being beyond the capabilities of the dinosaurs (and many species, especially land-based animals and those living in the upper reaches of the oceans) to survive. Whilst much work has been done on this from a variety of standpoints since then (for example, it now seems that more than one impact was involved, which would fit in with the ideas of those of us who believe that the fragments of disintegrated large comets are responsible for many impacts) the balance of the evidence still points to the basic veracity of the Alvarez idea. I hesitate to call that the 'original idea' since Napier and Clube had published a paper [6] which discussed the idea of frequent impacts by large celestial bodies onto the Earth, and their catastrophic consequences for life on the planet. I also hesitate to mention the fact that in the same year the (scientifically) appalling movie *Meteor* was released, and this may also have had a major role in bringing the impact idea into the public domain.

Through the decades following 1932 a few NEOs were discovered by chance, especially as wide-field telescopes such as Schmidts became available: asteroid 1566 Icarus was found in 1948 soon after the commissioning of the Mount Palomar large (1.2 m aperture) Schmidt. However, nowadays it is amusing to note that throughout the 1950s and 60s there was much debate about the origin of the lunar craters, and it was apparently a surprise to many when craters were found on Mars and Mercury. In fact, over the past couple of years some have found it remarkable that the Magellan radar data show large craters on Venus, even the extensive atmosphere of that planet affording little protection from substantial asteroids and comets. Impact cratering is now recognised to be a pervasive feature throughout the Solar System, the Earth being no exception.

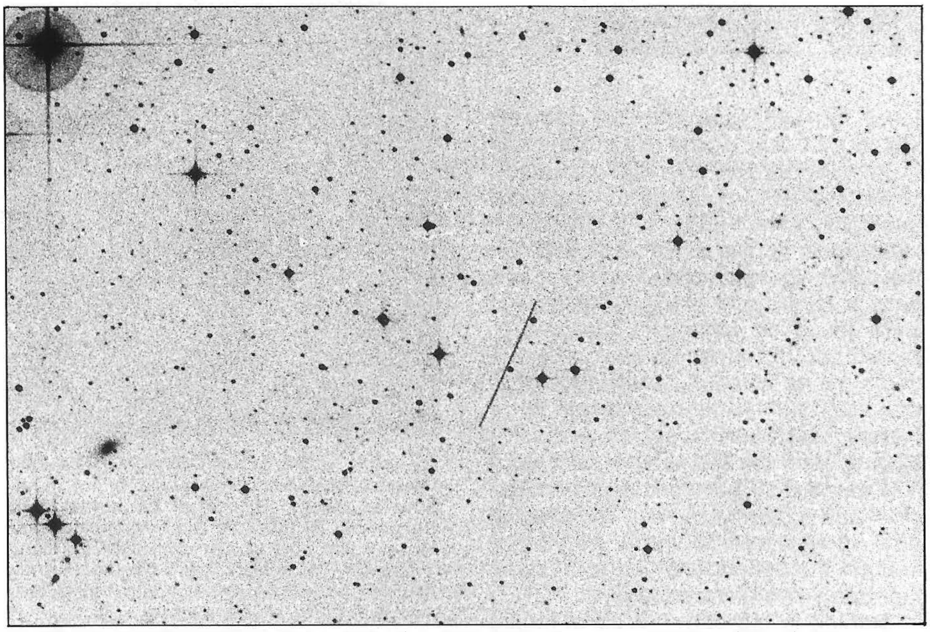
Starting in the early 1970s at Mount Palomar in California, using mainly the small (aperture 0.46 m) Schmidt telescope there, teams led by Eleanor Helin (Jet Propulsion Laboratory, California Institute of Technology) and Gene Shoemaker (Branch of Astrogeology, US Geological Survey) have expanded our knowledge of NEOs very considerably, and this work continues. After development efforts throughout the 1980s the team under Tom Gehrels at the University of Arizona have completed a dedicated search telescope equipped with a CCD chip. This telescope is called *Spacewatch*: it has a 0.9 m aperture and a small field of view, automatically scanning the sky with multiple strips of data being compared using sophisticated search software. It is this team which has discovered the 'nearest and smallest' asteroids like 1991 BA.



All planets (major and minor: a minor planet is another name for an asteroid) execute elliptical orbits about the Sun. The vast majority of the asteroids - billions of them - have low-eccentricity (i.e., near-circular) orbits between Jupiter and Mars, the outermost of the terrestrial planets. In this diagram two of the largest asteroids, Juno and Vesta, are shown. The dots are spaced by one week in their motion, being slightly further apart near perihelion since the velocity is higher at that point, and closer together near aphelion. However, some rogue asteroids have larger orbital eccentricities and therefore cross the paths of the planets. Shown here is a generic Apollo-type asteroid, with an aphelion near Jupiter and perihelion just outside of the orbit of Mercury: thus is could hit Mars, the Earth or Venus. For such a high eccentricity orbit the velocity (indicated by the spacing of the dots) is very high near perihelion, and the asteroid spends most of its time near aphelion, generally too far from Earth and too slow-moving to be spotted. Our main chance of discovering it is if the Earth is at the correct longitude such that the asteroid is near opposition (opposite to the Sun in the sky) as it moves between heliocentric distances of 1-2 AU (i.e. as it passes the orbit of Mars).

A Programme in Australia

The successes of the above programmes indicated the need for a search to cover the southern sky, and the Anglo-Australian Near-Earth Asteroid Survey (AANEAS) began in May 1990. Our *modus operandi* is as follows: photographs of the southern sky are routinely taken with the UK Schmidt Telescope (UKST; operated as part of the Anglo-Australian Observatory at Siding Spring, near Coonabarabran, NSW) as part of a number of celestial surveys: in particular the Second-Epoch Survey, repeating the observations done in the mid-1970s so that stellar proper motions can be determined. These are of use, for example, in providing accurate contemporary positions of faint stars for use in guiding the Hubble Space Telescope. These photographic plates are scanned by the AANEAS team as soon as they leave the drying room (i.e. within 12-18 hours of



A typical (negative) discovery photograph of a near-Earth asteroid. Amongst a field of stars (and a fuzzy galaxy just below centre and towards the left edge of the field) runs the streak due to an asteroid moving during a one-hour exposure with the UK Schmidt Telescope at the Anglo-Australian Observatory near Coonabarabran in New South Wales. That telescope takes photographs of the heavens with each plate covering an area about 6.4°-wide, or about one thousandth of the area of the sky. This close-up is about a quarter of a degree wide, or about half the angular width of the Sun or the Moon.
Courtesy Anglo-Australian Telescope Board

exposure) using a binocular microscope, special attention being paid to short trails which indicate an asteroid (or maybe a comet) which will have moved a measurable amount during the exposure. Each plate covers a field-of-view about 6.4 degrees on a side, or 12-13 times the lunar angular diameter: this renders a solid angle of about one-thousandth of the whole sky. The plates are about 36 cm on a side. Main belt asteroids move across the sky plane at a rate of about one-third of a degree per day, so that in a one-hour exposure (20-180 minute exposures are made) such a body will render a trail about a quarter of a millimetre long. Main belt asteroids are also predominantly of low inclination so that their trails are more-or-less aligned, with the major motion being in right ascension, and little movement in declination, so that they remain close to the ecliptic plane (the plane of the Earth's orbit). However, a NEO most often has a rather higher angular motion (a degree a day or more), which may be aligned in pretty much any direction in the sky, and also may appear well away from the ecliptic. Therefore if we search a plate taken near the ecliptic we may find 50-200 main belt asteroid trails, which are of no interest for this programme, and any NEO will appear as a needle in that haystack: but one which is often easily recognisable. A plate taken well away from the ecliptic most often renders no asteroid trails: but if one does appear then it is almost certain to be of interest. On the average 75-100 plates are taken per month, and from these we may find one NEO. Since it takes 30-60 minutes to search each plate, clearly the returns are low: but to put things into some perspective, since 1932 mankind has found only about 200 near-Earth asteroids, the vast majority in the last decade or so.

Once a probable NEO has been identified on a UKST plate, on subsequent nights it is re-observed so as to determine its orbit. Astrometric positions over the next 3-4 nights are generally essential, and then more observations in the next month so as to increase the arc of orbit over which it has been followed. Often a NEO can only be followed for a month or so, so that these early observations are essential such that it can be telescopically recovered in subsequent years. Follow-up observations are generally made by the AANEAS team (Rob McNaught, Ken Russell and myself) at Siding Spring using the Uppsala (Sweden) Southern Schmidt Telescope and/or the Australian National University's 40-inch telescope: the former is used for initial observations, until the orbit is sufficiently well-known for an ephemeris to be determined with high enough precision that the object can be found within the narrow field-of-view of the latter instrument. Follow-up observations may also be made, for objects in the southern sky out of reach of northern observatories, by astronomers at Mount John University Observatory in New Zealand, at Perth Observatory in Western Australia, or at the European Southern Observatory in Chile. Equally well, the AANEAS team makes follow-up observations for discoveries made by the US search teams, especially if they are rapidly moving south out of the reach of the northern observatories.

What Is Being Planned

No doubt due partially to media coverage in late 1990 the US Congress directed NASA to form committees to consider research programmes for

- ❑ Greatly increasing the present discovery rate of NEOs; and
- ❑ Responding to the hazard of any NEO found to be on a collision course with the Earth.

The exact language was as follows:

> *"The committee believes that it is imperative that the detection rate of Earth-orbiting-crossing asteroids must be increased substantially, and that the means to destroy or alter the orbits of asteroids when they threaten collision should be defined and agreed upon internationally.*
>
> *The chances of the Earth being struck by a large asteroid are extremely small, but since the consequences of such a collision are extremely large, the Committee believes it is only prudent to assess the nature of the threat and prepare to deal with it. We have the technology to detect such asteroids and to prevent their collision with the Earth."*

The first NASA committee ('Detection') was chaired by David Morrison (NASA-Ames Research Center, California), and two of us from the AANEAS team served on that committee. The report of the committee was published in March 1992. I also served on the second committee ('Interception'), which was chaired by Drs John Rather and Jurgen Rahe (NASA HQ, Washington, DC), and met at Los Alamos National Laboratory (New Mexico) in mid-January 1992. The report of that committee should have been published by the time that this article appears.

Returning to the Morrison committee, it may be of interest to know what is to be recommended. A three stage project is envisioned, to be named SPACEGUARD for the similar (although radar-based) project described by Clarke back in 1973. These three stages are as follows:

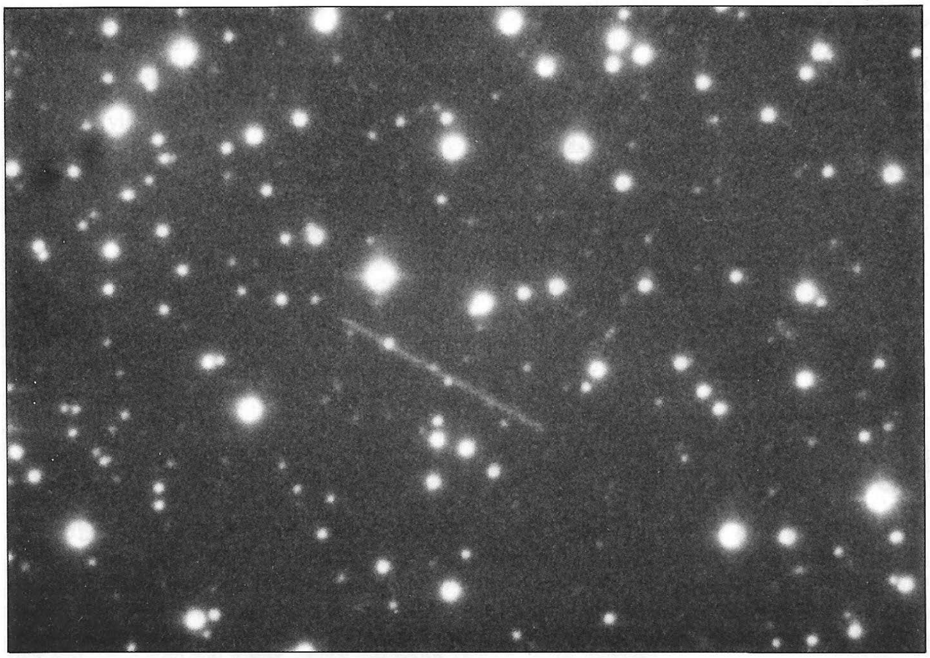
SPACEGUARD 0

This is a simple continuation and expansion of the current search programmes, so that over the next five years a large enough sample of NEOs is collected such that future searches may be optimised: it is estimated that there are at least 2-3,000 near-Earth asteroids over 1 km in size, and ~10,000 over 0.5 km, of which only a tiny percentage is now known.

SPACEGUARD 1

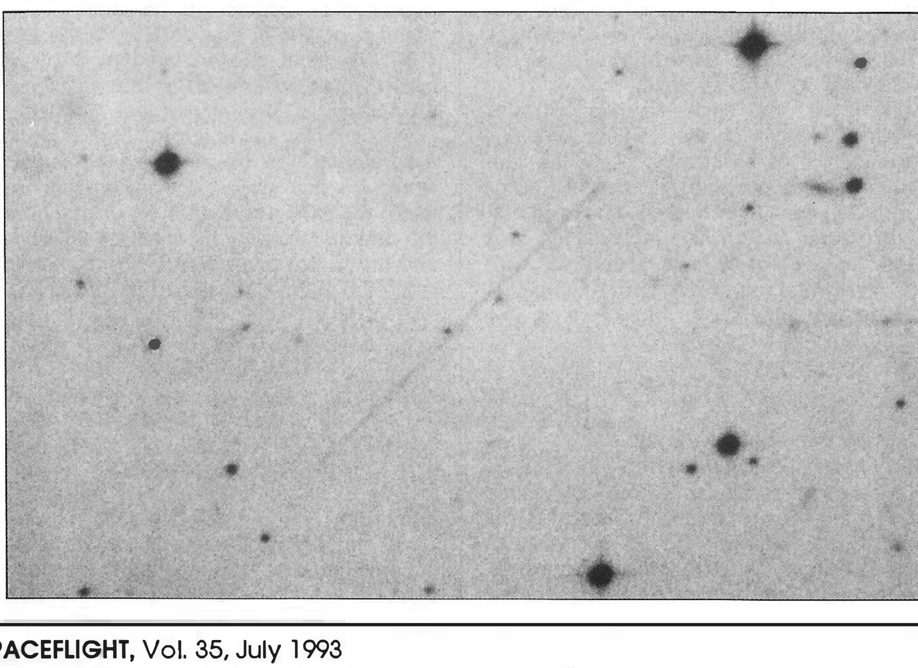
This is to be a coordinated network of at least six dedicated search telescopes, with a central administration/

orbit computation bureau to handle the incoming data. Wide-field (2-3°) telescopes with 2-3 m apertures are planned, with mosaics of CCD chips scanning the sky. These would be spread over all latitudes and longitudes, with the southern hemisphere contingent being In Australia, Chile and southern Africa. Narrow-field follow-up instruments are also required. It is anticipated that the discovery rates will be huge: several thousand NEOs (mostly very small: 10-100 m) would be found each month. Despite this, it will take 15-20 years to achieve the aim of essentially-complete discovery of all Earth-approaching asteroids larger than 1 km. The aim here is that each object can be integrated forwards by computer so as to find whether it may impact the Earth in the foreseeable future: the next century or so. It should be possible to project any impact many years ahead (unless we are unlucky and an object is found on the very orbit in which It Is going to hit our planet), and then the plans laid by the Rather/Rahe committee come into play. However, long-period comets (LPCs) will only be found some 6-12 months ahead of potential impact, so that they pose an especial problem.



A positive print of the discovery photograph of asteroid 1991 DA. This peculiar asteroid passes perihelion near Mars, but has such a large orbital eccentricity that it then moves out past Jupiter, Saturn and Uranus before again returning to the inner solar system, each lap taking 41 years to complete. By following its orbital evolution backwards and forwards for tens of thousands of years it has been possible to show that 1991 DA may at some stage occupy an Earth-crossing orbit, so that an impact by this large body, estimated 5 to 8 km, is not out of the question, although unlikely.
Courtesy Anglo-Australian Telescope Board

The very faint trail caused by Earth-crossing asteroid 1991 FB in its discovery shot, taken on 18th March 1991. On the original photographic plate the trail is rather less than a millimetre long, representing the angular distance that the asteroid moved in 70 minutes.
Courtesy Anglo-Australian Telescope Board



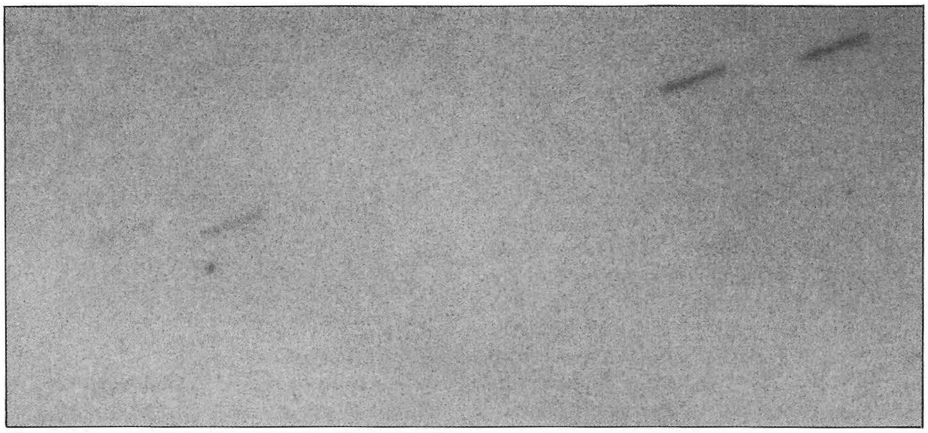
SPACEGUARD 2

This phase would partially solve the above problem. This phase would encompass larger telescopes (4-5 m class) to look for fainter objects. For LPCs, which spend many years passing though the giant planet region, most likely two telescopes, one in each hemisphere, would suffice. If it is deemed necessary to try to build up an inventory of all smaller Earth-approaching asteroids then more instruments would be needed; or a space-based system may be constructed. Such projects are very much in the distant future: in the immediate future (the next 5-10 years) it is desirable that 'Spaceguard 0' proceed immediately, and 'Spaceguard 1' receive funding to allow operations to begin by 1995-96. The total cost for the six-telescope system with a 20 year programme is estimated at US$300 million. These funds would need to be raised from several governments: the asteroid hazard is one faced by the whole world, with a large impact anywhere menacing the whole of mankind.

It may have been noted so far that no role for radar has been mentioned. In fact, radar is not a viable search tool with presently-available technology. Even with the most powerful planetary radars available (Goldstone in California and Arecibo in Puerto Rico) it is only possible to detect echoes from NEOs if:

- ❑ An ephemeris good to near-arcminute accuracy is available;
- ❑ They pass within about 10 million kilometres of us (less than a tenth of an astronomical unit), for typical NEO sizes; and
- ❑ They are at declinations reachable with the above radars.

Having written, then, that radars are not practical search instruments, now it must be pointed out that they are invaluable follow-up devices. In order to derive an orbit for a NEO which is sufficiently precise to make numerical integrations for decades into the future meaningful, optical astrometry over several apparitions (meaning a decade or more) is necessary, since the uncertainty in the NEOs position in space from optical observations may be thousands of kilometres in the plane of the sky. However, radar observations can render both the dis-



The main use of the UK Schmidt Telescope is in performing southern sky surveys, with discoveries of near-Earth asteroids made when these occur by chance on the photographic plates. However, at times deliberate shots of asteroids are taken, this being an example. Asteroid 4660, Nereus, was discovered in 1982 from Mount Palomar Observatory, California, and was recognised as being one of the most accessible celestial objects since it has a relatively low geocentric velocity. It is a plausible target for future spacecraft missions, and maybe eventually for a space mining venture. However, it was expected to be very faint in its 1990 return close by the Earth, and so the UKST was tracked across the sky at a rate equal to the motion of the asteroid. In this 20 minute exposure Nereus appears as a single spot below centre at left, with the streaks being stars relative to which the asteroid was moving.

Courtesy Anglo-Australian Telescope Board

tance and the velocity in the line of sight with high accuracy: a single radar detection may be worth as much, in terms of improving the ephemeris, as ten years of optical astrometry. For this reason it is desirable for project SPACEGUARD that more access to the Goldstone and Arecibo radars be obtained (sometimes at short notice), and the present upgrade of Arecibo will also help to improve the detectability of small NEOs. However, a southern hemisphere installation is also very desirable. Australia is the only southern hemisphere nation with the technological infrastructure necessary to build a planetary radar of this type.

Now to return to the second NASA committee, the one delegated to recommend how the NEO hazard should be tackled: interception and deflection, or destruction, or evacuation of the target area (at least for the smaller objects)? This committee met at Los Alamos, New Mexico, in January 1992, and consisted of about a dozen astronomers, a similar number of space scientists and engineers from academia, and a large contingent from the US military and the Strategic Defense Initiative (SDI) programme: prominent amongst the latter was Dr Edward Teller. I was the only member of that committee working outside of the USA. For the large NEOs which are the target of SPACEGUARD, most likely no object will be found which will strike the Earth in the foreseeable future: and even if one were found on an orbit which will hit us, the likely warning time is many years, in which case the appropriate action is to inter-

Duncan Steel

Comet Swift-Tuttle and a Question of Probability

On September 26, 1992 a comet was spotted in the northern sky by a Japanese astronomer, Tsuruhiko Kiuchi. It did not take long for it to be realised that this was no ordinary comet, but in fact a very special body, Comet Swift-Tuttle, which had not been seen since 1862 when it was discovered by American astronomers Lewis Swift and Horace Tuttle.

Periodic comet Swift-Tuttle (hereafter P/ST) is the intrinsically brightest of all known periodic (regularly-returning) comets, and therefore is one of the largest of all such bodies, with a nucleus probably 5-10 km in size, although it may be even bigger. In 1986 people spoke of Comet Halley being a 'once-in-a-lifetime' experience since it comes back only every 76 years; in that case P/ST is a 'once-in-two-lifetimes' experience since we now know that it only returns every 130 years or so.

Although I have written that these are 'regularly-returning', in fact P/ST was expected, on the basis of the 1862 observations, to be coming back in 1980-82, but it was not seen. This led cometary astronomers into a bit of a quandary: had it formed an insulating crust, perhaps, so that it was now asteroidal in nature and thus missed a decade ago? Another solution was that possibly the positional measurements in 1862 were slightly incorrect meaning that its orbital period was a little longer than the 118-120 years which had been calculated. Dr Brian Marsden, a British astronomer working at the Harvard-Smithsonian Center for Astrophysics, had suggested this in a paper in 1973, saying that it was possible that P/ST was identical with a comet observed from China by a missionary by the name of Kegler, in 1737. If this were the case, Marsden wrote, then P/ST would not reappear until 1992. He was right, and Kiuchi found the comet much where Marsden's predicted ephemeris placed it. In fact, after Kiuchi's announcement it was found that a group of Italian amateur astronomers had photographed the comet back in January 1992; it is a great shame that their observations were not announced to the community since accurate positional measurements well before perihelion passage (in December 1992) would have been invaluable in determining its precise orbit.

For the past several years astronomers have been on the look-out for P/ST, expecting it to be nearby, since the meteor shower which it causes (the Perseids) has shown an increase in activity in the early 1990s, culminating in a brief but distinct flare in activity in 1992 as the Earth passed through the longitude of the comet's node (i.e. where the comet's orbit crosses that of our planet). The Perseid meteor shower is one of the best known, and most intense, northern hemisphere showers, with a peak occurring on the night of August 11-12. Since the shower coincides with the feast of St Lawrence, the shower is also sometimes called the 'Tears of St Lawrence'. Meteor enthusiasts are gearing up for a spectacular display in 1993, since many more meteoroids are expected to lag behind the comet (rather than preceding it to the Earth's orbit).

The fact that meteoroids from P/ST can hit the Earth also suggests that the comet itself could strike our planet. This is indeed the case, and if we had been unlucky P/ST could have clobbered us this time around, giving us only a few months warning: not enough time to do anything constructive. The reason that an impact is possible is that the orbit of P/ST not only crosses that of the Earth (i.e. passes closer to the Sun than 1 AU) but also the two orbits are very close to intersecting in three-dimensional space. In an International Astronomical Union Circular published on October 15, using the observations of P/ST from 1992, 1862 and 1737, Marsden pointed out that the next return would occur in 2126 and an impact on August 14 of that year was possible.

A possibility, but is it probable? A crude estimate for the likelihood of an impact would be gained just by saying that we might (at this early stage) be uncertain of the date of return by as much as 25 days: and the comet takes about 3.5 minutes to cross the Earth's path, so that the probability of an impact is about 25 days divided by 3.5 minutes, or about one in 10,000.

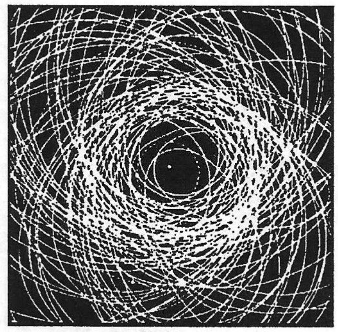
Is this too small to worry about? Well look at it this way. If mankind manages to stabilise its population such that there are only 10 billion people alive in 2126, then at this stage our expectation of lives lost is 10 billion divided by 10 thousand: one million. I would say that such a calculation means that we should do all that we can now in order to narrow down the odds. (I might also note that the probability of a

cept the object well away from the Earth and change its velocity by the small amount necessary so as to ensure that it will miss our planet: a velocity change of just a few centimetres per second would be ample in most cases. Most likely the use of nuclear explosives would be necessary, although an alternative scenario would be to cause a much smaller asteroid in the main belt to intercept the problem asteroid as it passes aphelion (the furthest point in its orbit from the Sun), the collision causing a large enough change in its orbit to ensure our safety.

So Began Project SPACEGUARD

Having had its concept of the Earth and our safety on it shaken up by the scientific discoveries of the last decade or so, it seems that at last mankind might be galvanised into action to ensure that what led to the demise of the dinosaurs does not lead to our downfall as well. The likelihood of your dying as the result of an asteroid impact might seem very slight (how many people do you know who have expired in this way?) but this is because such events occur on timescales much longer than the human lifetimes. Nevertheless, these very occasional events have the potential to cause a huge number of fatalities: the total downfall of civilisation or even the extinction of the human race is not out of the question. In fact, a formal calculation of [frequency of large asteroid impacts] times [estimated deaths] indicates that you have about a 1 in 2000 chance of meeting your end in this way: approaching your chance of dying in a car accident or being shot, and larger than the probability that you will die in an air crash.

The SPACEGUARD idea has come full circle. After the NASA committee picked up that title from *Rendezvous with Rama* as a suitable appellation for an international near-Earth asteroid search, the editorial staff at *TIME* magazine asked Arthur C. Clarke to write a fictional piece about its possible implementation. This Clarke has done in what he terms a "complete novel in 5,000 words", with the title *The Hammer of God* [7]; this he has now expanded into a full-length novel [8]. But to close, we should go back to *Rama* and quote Clarke again: "So began Project SPACEGUARD".



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5. R. Baldwin, *The Face of the Moon*, University of Chicago Press, 1949.
6. W.M. Napier and S.V.M. Clube, *Nature*, 282, 455, 1979.
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8. A.C. Clarke, *"The Hammer of God"*, Bantam Books, 1993.

Adds a Postscript

civilisation-ending impact from some as-yet unknown asteroid or comet prior to 2126 is about 10 to 20 times as high; that is, about 1 in 500 to 1000).

What could be done to narrow down the odds? One thing, as Marsden urges, is to track the comet over the rest of the decade so as to determine as accurately as possible when it will return. In particular P/ST must be observed after it passes beyond 3 AU from the Sun since then the non-gravitational forces (due to evaporating water under solar heating) which perturb the comet's orbit, will have switched off. The drawback is that without the cloud of highly-reflective water vapour about the cometary nucleus, P/ST will be very faint, requiring large telescopes to follow it. On top of that it will be far in the southern sky, out of the reach of many of the world's leviathan instruments. Hopefully the new generation of 8-10 metre class telescopes now being built in Chile (such as the US-British Gemini project) will be available by the late 1990s so as to take over from the 4 metre telescopes now available in Chile and Australia. In fact, improving technology may even enable us to follow P/ST around its whole orbit, passing out beyond Neptune and Pluto.

The subject of whether P/ST might hit the Earth 'next time around' has become a hotly-disputed debate. Normally-conservative scientists have become embroiled in publicly-aired arguments, largely because of the huge amount of international press coverage which followed Marsden's October 15 suggestion (for which the present author must admit some responsibility, having made this suggestion widely-available through a talk given at the Australian Space Development Conference in Sydney soon thereafter, also supplying additional information to the Reuters correspondent who was present). For example, all British national dailies carried the story on October 26-27. For an example of phenomenally-poor journalism, see the front page of *The Times* for October 26, plus an absurd editorial: a letter by Marsden published on October 31 corrected some of the silliness.

Following this press coverage, and in particular an item in the *New York Times* of November 3, Marsden and Dr Don Yeomans (Jet Propulsion Laboratory, California) have been heatedly arguing over whether we know enough about the dynamical behaviour of P/ST to be able to say whether an impact in 2126 is a possibility, or can be ruled out; Yeomans believes the latter, whilst Marsden thinks that more data are needed. One source of important data is the history books: ancient records of past apparitions of P/ST can now be identified, since we know that the orbital period is closer to 130 years than 120, and Dr Graeme Waddington (University of Oxford) has been prominent is rooting these out. Waddington believes that a bright comet seen in 188 AD is a certainty, with some other possibilities, and Marsden also suggests comets recorded in 60 AD and 69 BC. With observations, *albeit* crude, stretching over two millennia, a much better idea of the long-term motion of the comet can be gained.

In fact John Chambers, a British research student from the University of Manchester, where he works with Dr Mark Bailey, is currently doing some research on P/ST with Marsden at Harvard. Chambers finds that P/ST is likely to occupy a stable resonance associated with Jupiter, whereby the comet has an orbital period exactly eleven times that of the giant planet, for at least the next 10,000 years. This would mean that P/ST will continue in much the same orbit as at present for at least ten millennia, so that even if it does miss us in 2126, as is most likely, it will have many future chances to plough into the Earth.

The final question all will have, of course, is what would happen if P/ST does literally strike home? The answer makes sobering reading. The impact velocity of P/ST upon the Earth, should it actually collide with us, is known quite accurately; it is about 60 kilometres per second. However, the size of the cometary nucleus, and its density, is not so well determined. Assuming a minimal diameter of 5 km, and a density that is just the same as that of water, the kinetic energy released in an impact would be equivalent to about 20 million megatonnes of TNT, which is over one billion (one thousand million) times as high as that released by the Hiroshima bomb. (A useful rule of thumb is the fact that at a speed of 3 kilometres per second any object has kinetic energy equivalent to the chemical energy of its own mass of TNT; at 60 km/sec the kinetic energy is equivalent to 400 times the explosive power of that mass of TNT). This is of the same order as the likely energy of the impactor (or impactors, since it now seems that more than one object was responsible) which arrived at the end of the Cretaceous geologic period, apparently wiping out the dinosaurs. Most certainly if P/ST were to hit the Earth it would have global effects which would include the deaths of many, if not all, of the human race.

Behind the Soviet Space Curtain

The Soviet Space Programme has many successes and "firsts" to its credit which were justifiably well-publicised by the Soviet authorities at the time. But, in contrast to the West, they revealed nothing in advance about their preparations and future launch plans.

Questions that arise are:

(i) How much did the West know about the Soviet work and intentions?

(ii) How much is known now that 'glasnost' prevails?

In this issue, we turn the clock back and shed more light on these aspects of Soviet Space History with:

Soviet Space

CIA Documents Reveal

Peter Pesavento **has recently had access to two previously classified documents about the Soviet space programme, which were made available to him on request through the USA's Freedom of Information Act.**

Much of the information in these documents helps to fill in gaps on the history of the USSR's space programme and provides some insight into how much was known by the US intelligence community about Soviet space activities (ranging from good to excellent), as well as the CIA's abilities to prognosticate future efforts in space (somewhat more murky).

Introduction

One of the documents is a National Intelligence Estimate (NIE) of the USSR space programme dated 2 March 1967 [1] and the other is a bulletin on the recovery of Zond 5 dated 23 September 1968 [2]. Both documents are sanitised versions of the original reports with about 90% of the text remaining intact.

One gets the sense from reading these documents that any space activity performed by the Soviets (whether launches, construction, experiments, probable funding allocations, or policy decisions by the USSR) did not escape the notice of the US intelligence system.

The bulk of the interesting material on the Soviet Union space programme lies in Ref. 1. I will concentrate on a selection of topics plus a short critique of the CIA predictions in each of the following sections.

* * *

Manned Space Programmes

Frequently mentioned in the report [1] is "Area J", a major new launch facility at Tyuratam:

> That will be able to take vehicles with a first-stage thrust in the 8 [million] to 16 [million] pound range; it will be completed next year.

It is obvious that the N-1 launch pad complex is what is being discussed. According to the NIE, it had been under construction for the past 3½ years.

Manned Lunar Programme

One of the surprise pieces of information is that since early 1965, the CIA had been estimating that:

> The Soviet manned lunar landing program was probably not intended to be competitive with the Apollo program as then projected, i.e., aimed at the 1968-1969 time period. We believe this is probably still the case.

However, hedging their bets, the CIA states later on that:

> All things considered, we estimate that the earliest the Soviets could attempt a manned lunar landing, would be mid-to-late 1969...the most likely date is sometime in the 1970-1971 time period.

Several factors militated against the USSR being able to compete with the Apollo timetable, including the status and pace of construction at Area J:

> These indicate that the launch system will probably not be ready for test until about mid-1968. When a launch vehicle is available, we would expect to see a series of tests for man-rating the system extending over at least a year before a lunar landing would be attempted. In the meantime, the Soviets will need to check out a new spacecraft, to test reentries at lunar return velocities, and perhaps to develop a water recovery capability...may also need to test rendezvous and docking techniques and equipment.

Manned Circumlunar

It is interesting to note that the CIA had already by this time (1967) divided the USSR's assault on the Moon into two separate manned projects. The CIA also expected an early circumlunar mission to be attempted because it:

> Would pay important dividends in terms of prestige, and could be a means to offset some of the propaganda value of the US Apollo program.

To achieve this early mission (first half of 1968), the Soviets could attempt to execute this by using existing hardware:

> In order to do so they would need to add a Venik upper stage to the SL-9 [Proton] system, man-rate this combination with an SL-8 final stage, and modify the Voskhod spacecraft to give it midcourse correction capability. This combination could put a payload of about 15,000 pounds on a circumlunar trajectory, which would permit the Soviets to send a crew of two on a circumlunar flight. Alternatively, the Soviets may choose to utilise a new...upper stage designed to be flown with the SL-9 system and the new spacecraft [Soyuz] with a midcourse guidance capability inherent in its design.

Manned Space Station

In the section on space stations, the discussion focuses on two station programmes. One, launched by the SL-9:

> Weighing approximately 50,000 pounds and capable of carrying a crew of three or more could probably be placed in Earth orbit in the first half of 1968,

and the other:

> A very large manned space station.

Of the Proton-launched station it was said:

> ...new spacecraft, rendezvous, docking, and extravehicular operations could extend the operational lifetime of the station to several months and perhaps as long as a year.

Of the larger station it was said that:

> Development will probably be one separate from their manned lunar landing program and probably not be conducted concurrently with that program at Area J...A space station of this size (200,000 to 300,000 pounds) would permit a permanent or semipermanent space laboratory to be placed in orbit by mid-1969 at the earliest...the most likely date is sometime in the 1970-1971 time period.

Such prominent mention of the large space station and the lack of information (despite glasnost) from the Russians about this manned project may indicate that it may be one of the topics to be talked about in more detail by the Russians in the near future.

Voskhod

Probably some of the more interesting surprise material dealing with the manned programme concerns the Voskhod project. One of the facts not previously known is that Cosmos 47, the precursor to the first manned flight of the series, had dummies on board. Although Cosmos 47 was the only full flight test of the Voskhod carrying all

Programme
New Historical Information

BY PETER PESAVENTO
California, USA

of the associated subsystems for manned flight, the NIE mentions that four other Cosmos missions (22, 30, 34 and 45), in addition to performing their primary reconnaissance missions, served to man-rate the Venik propulsion stage and that they:

> Possibly provided testing of the Venik/ Voskhod compatibility and of Voskhod structural integrity.

Another section discussed what the Soviets failed to carry out as pertaining to:

> Certain activities...essential to their manned space program, and which... ...they could have undertaken during 1965 or 1966.

The discussion included mention of a long-duration manned flight:

> Scheduled for the spring of 1966 and later cancelled.

The Cosmos 110 mission (of 22 days duration):

> Was probably intended to support a month-long flight with dogs, the equivalent of 12 man days.

In a 1990 ***JBIS*** paper, I discussed the Voskhod project, as well as the evidence for a planned long-duration manned mission in the spring of 1966 [3].

Launch Vehicles

Mention is made that all major Soviet space activities from 1957 to mid-1965 used military boosters fitted with additional upper stages, and that to:

> Undertake more complex space missions in the future...the Soviets are evidently now being forced to develop large boosters specifically for the space program.

The two boosters most discussed are the SL-9 Proton, and a "new booster" which we now know to be the N-1.

Proton (SL-9)

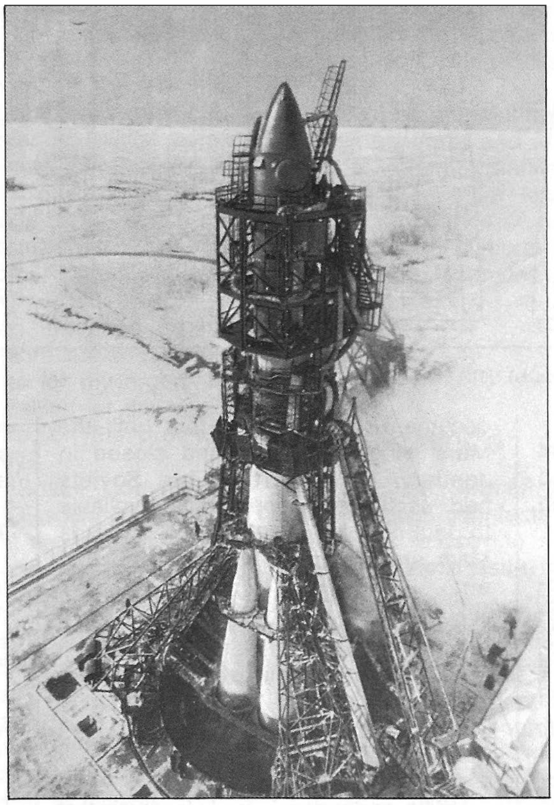
The CIA believed that the Proton was the first Soviet booster developed solely as a space launcher, although:

> It is possible that this booster was originally to serve as a delivery system of the 100-MT (megaton) weapon (of which Khrushchev boasted in the early 1960s),

but the CIA believed that a miliary system was very unlikely to have been the Soviet objective.

Estimates of the rocket's thrust of 2.5 to 3 million pounds (the actual value is 2.7 million pounds) and payload capability of about 27,000 pounds (the actual value is 26,900 pounds) reflects well on CIA estimates of missile capabilities. There is also mention in a sanitised section that the Proton would soon employ a third stage, providing:

> The Soviets with the capability to attempt a variety of advanced space missions including manned space stations and manned circumlunar flights as well as more ambitious unmanned planetary missions. The addition of a third stage employing conventional propellants, would allow a payload of some 50,000 to 60,000 pounds to be placed into near-Earth orbit...(and a) payload of approximately 15,000 pounds could be placed into a lunar transfer trajectory...a payload of this weight would be adequate for the Soviets to attempt a manned circumlunar flight.



Voskhod 2 rocket on the launch pad.

So as early as February 1967 the Proton was already linked by the CIA to the circumlunar programme. The NIE also states that it was expected that initial flight tests of the SL-9 with a third stage would occur in the first half of 1967, with manned flights beginning some six months to a year later.

N-1

Area J construction at Tyuratam made it clear that another booster "much larger" than the Proton was under development. The magnitude of Area J:

> Appears to be...the same...as the US Apollo launch complex at Merritt island.

The only identifier for the N-1 in the NIE document is when it was described as the "J-Booster". The CIA thought that it was possible that the SL-9 would be incorporated into its second and third stages; however, if:

> The entire vehicle is new,...and uses conventional propellants in all its stages, it could probably not be man-rated before 1970 at the earliest.

The booster itself, as of February 1967, had not yet been seen.

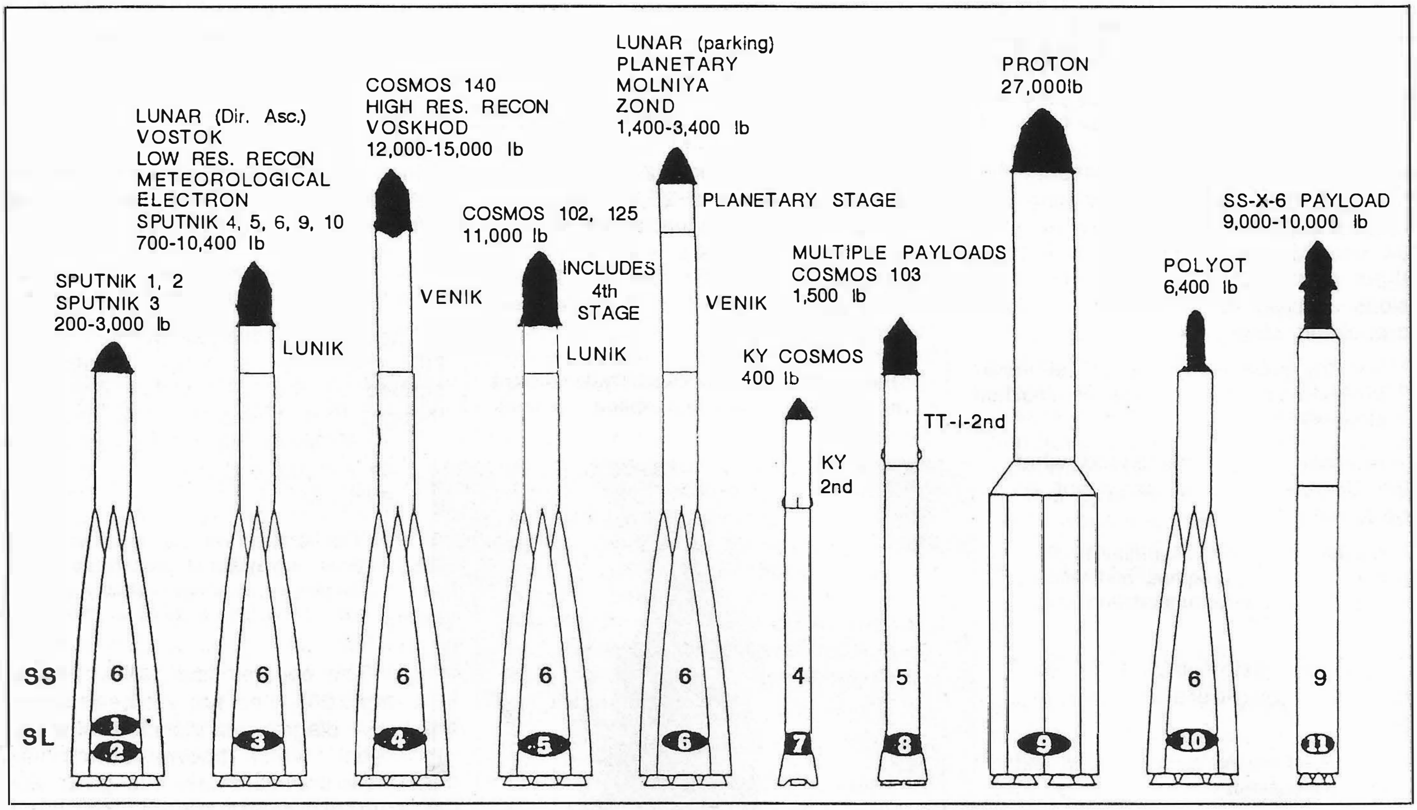
A diagram is included with the report which shows launch vehicle configurations and gives estimated payloads. US photoreconnaissance capabilities by this time (1967) were already excellent, as determined by the accurate (although somewhat stylised) depictions of the boosters. It is interesting to note that the payload shrouds - especially of the SS-X-6 "Fractional Orbital Bombardment System" and the Polyot vehicles are being shown for the first time.

Expenditures

The CIA's estimates on the expenditures in the Soviet space programme during the mid-1960s are the first to be released for public reading. Indeed, the estimates of expenditure indicate that Soviet spending was lower than comparable US spending at the time, but somewhat higher than figures released by the former USSR ministry of defence last year [4]. In the CIA's own words:

> We estimate that expenditures in the Soviet space program have been rising at an average annual rate roughly equivalent to US$1 billion from 1962 when about $1 billion was expended, through 1966 when about $5 billion was expended. Much of this increase is accounted for by the major launch systems at Tyuratam and the associated program represented by the construction of Area J. Area J is not yet complete...but we believe that the program is sufficiently advanced to permit the overall cost of the Soviet space program to level off shortly; and hold at about US$5.5 billion per year for the next few years.

The costs include both the military and nonmilitary portions of the Soviet programme.



Soviet space launch vehicles (estimated payloads) [1].

Launch Failures

Tabular data in the NIE document presented a higher-than-expected number of failures in the lunar and planetary programmes.

For their lunar project (to 28 February 1967) the Soviets had six successes, 1 partial success, and 19 failures. For three straight years (1963-1965) they experienced only launch failures. The launch dates of identified failures (since 1958) were:

4 December 1958;
18 June 1959;
15 April 1960 (not announced by the USSR, "insufficient velocity. Nearest approach to Moon was 100,000 miles");
4 January 1963 (parking orbit; 4th stage failed);
3 February 1963 (parking orbit not achieved);
20 April 1964 (parking orbit not achieved);
12 March 1965 (fourth stage failure);
10 April 1965 (third stage failure);
1 March 1966 (failed to eject from parking orbit).

The report also mentions that three further launches using the SS-6 in direct-ascent missions failed - two in the fall of 1958, and one in early 1960.

There was also mention that it was expected that Luna 10 and 11 were expected to return photographs of the lunar surface (but did not), and that Luna 12 sent back photographs of poor quality.

Planetary

A very dismal picture of Soviet planetary efforts is painted in the NIE document, which states that until the Mars window opened and closed in January/February 1967, the Soviets had used every opportunity available to launch planetary probes towards Mars and Venus. It was reported that an:

> Unprofitable planetary program - 16 consecutive failures - has been curtailed in an attempt to reduce expenditures for space.

Or the reason for the hiatus may be due to a temporary suspension:

> Until a new system is ready for use in that program.

Planetary missions identified by the CIA as launch failures include (since 1960):

10 October and 14 October 1960 (Mars, parking orbit not achieved);
25 August, 1 September and 12 September 1962 (unsuccessful Venus launches);
24 October, 4 November 1962 (Mars launch failures);
19 February 1964 ("probable engineering test of planetary probe");
27 March 1964 (Venus attempt, 4th stage failure, announced as Cosmos 27);
30 November 1964 ("Zond II power encountered difficulties in first day of flight");
23 November 1965 (Venus probe attempt, labelled Cosmos 96).

Included is a table of all space launches of the major Soviet space programmes from 1960 up to 28 February 1967. It is worthy of note that Proton had two successes in 1965 and one failure in 1966. Two failures are reported in what appears to be the dog satellite programme - on 28 July 1960 and 22 December 1960.

Technical Items

The information in this section contained hints at data collection other than photoreconnaissance. Despite some excisions by the CIA's declassification authorities, it remains possible to come to reasonable conclusions about Soviet capabilities in the mid-1960s dealing with on-board spacecraft battery systems (especially for use on manned spacecraft), and efforts dealing with non-conventional propellants.

Batteries

The majority of spacecraft flown by the Soviets to early 1967 had either used chemical batteries or solar cells. Apparently samples of Soviet chemical batteries obtained by the CIA indicated weight efficiencies of about 55 watt-hours/pound (although I think it would probably be more accurate to state watt-hours/kilogram):

> Which compares favourably with current US capabilities.

The CIA felt that this figure could be increased to 70 watt hours/pound if the Soviets felt a need to save weight. Radioisotope/thermo-electric conversion systems used in:

> Two Soviet satellites orbited in 1965 delivered [between 100 and 200] watts of electric power respectively, a capacity far too small to be used in a life support system.

Fuel cells using hydrogen-oxygen reaction were undergoing "performance testing", and it was stated that:

> The Soviets could have fuel cells suitable for short space missions now.

Propellants

Interspersed in parts of the text is mention of high-energy propellants. There is interest in propellants such as "liquid hydrogen and fluorine", although:

> To date, no Soviet flight tests or space launches have been detected which used high-energy propellants in any of the stages. However, we believe some phases of static testing are now being conducted and flight testing could begin in 1968-1969, possibly as part of the development of the system intended for Area J [the N-1 rocket], and that about 1970 or shortly thereafter high-energy upper stages could be man-rated and available for use...

In the discussion on the Proton:

> The use of a high-energy third stage would allow a 70,000-80,000 pound payload to be orbited...

Despite glasnost, no review papers or reports released by the Russians has shed any light on this very interesting but little-known facet of their space effort.

Nuclear

In 1967, the CIA had found no evidence that the USSR was developing a nuclear rocket engine for interplanetary propulsion:

> Although they are continuing research which could be applicable to such a development. It would probably take the Soviets some 5 to 10 years after the initiation of the program,

to have an engine ready for testing.

Perceived Weaknesses in Soviet Programme

Some of the highlighted weaknesses focus on the USSR's command and control network:

> Some existing deficiencies relate to point-to-point communication within the USSR...
> The lack of a worldwide tracking and communications network may handicap the Soviets in the performance of some orbital operations and will be a severe handicap if the Soviets attempt to control several operations systems, each consisting of several orbiting vehicles.

The number of hours (8 to 16) daily that the deep-space tracking facilities in the Crimea could be available for lunar flights is discussed and it is pointed out that this would be inadequate for manned lunar flights that would need:

> 24 hours a day basis...to help insure the safety of such missions. The Soviets could, however, undertake manned lunar flights even with their limited tracking and communication capability by accepting the calculated risk of not being able to communicate with the spacecraft for certain periods of time.

No evidence was detected that Soviet surface ships had been in the process of being integrated into a high-capacity communications network with the antennas in the Crimea:

> But the development of a system using such shipborne relay links is well within their capability.

Further discussions also cover the lack of a demonstration of rendezvous and docking, water recovery of spacecraft, no tests of spacecraft reentries at lunar return velocities, and the lack of any manned flights since March 1965. In hindsight, 1967 was the year when many of these concerns were to be addressed.

Photoreconnaissance Missions

According to the NIE document, this programme has:

> Enjoyed one of the highest priorities in the entire Soviet space effort...(and) the most successful of all Soviet unmanned space programs.

Two types of vehicles are employed in their programme - low resolution ("10 to 30 feet under average conditions") and high resolution ("of the order of 5 to 10 feet under average conditions...Under ideal conditions the resolution could be somewhat better").

Mention is also made that the Soviets already had a "photovideo system" in operation. With the first launch attempt in 1961 a failure, the Soviet reconnaissance programme recovered and was thriving:

> In 1962, 5 successes/1 failure;
> 1963, 7 successes/2 failures;
> 1964, 11 successes/1 failure;
> 1965, 17 successes/1 failure;
> 1966, 20 successes/2 failures;
> and to late February 1967, 3 successes.

According to the CIA:

> The launching of recoverable photographic and Elint reconnaissance satellites from Tyuratam and Plesetsk will probably continue at about the present rate until similar missions of longer duration or manned orbital reconnaissance platforms are employed.

Predictions

Despite the accuracy of gauging present Soviet space capabilities (i.e. for 1967), the NIE document definitely admits to having problems when trying to identify intent. The problem, so succinctly stated in the report's first paragraph, is:

> To estimate Soviet capabilities and probable accomplishments in space over the next 5 to 10 years.

It appears to have been quite a daunting task.

One interesting prediction that never took place was the expectation that the Soviets had:

> Planned some form of space spectacular during 1967 in connection with the 50th anniversary of the October Revolution or the 10th anniversary of Sputnik 1. This might involve the orbiting of a 25 ton space station, a new manned spacecraft, or some activity involving both. We cannot predict the precise nature of the spectacular but believe that the event will be confined to near-Earth space.

Now is a good time for our Russian colleagues to hold forth if a 1967 space spectacular was indeed actually planned.

Looking farther ahead, the CIA expected a circumlunar flight in the first half of 1968, or a long-duration space flight in near-Earth orbit. For the early 1970s, a manned lunar landing and a large (200,000 pound) space station were expected. Looking back in hindsight, it is now obvious that the CIA was somewhat premature on predictions of the arrival in orbit of the Salyut space stations, only six months ahead of actual Soviet capabilities for sending men on a circumlunar mission, about on target for a manned lunar landing mission (with the caveat that this is being written without complete knowledge of Soviet aspirations for manned lunar flight in 1969), and nowhere near accurate in predictions of a large manned space station.

The document does demonstrate the comprehensiveness of the efforts of the USA's intelligence network to gather information on America's arch rival. For the most part, the efforts indicate that President Johnson was not only getting timely information, but for the most part, accurate information on the status of the Soviet space programme.

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2. Central Intelligence Bulletin, Excerpt. (Title deleted.) "USSR: The Soviet recovered Zond 5, an unmanned circumlunar probe, in the Indian Ocean yesterday." Dated 23 September 1968. (Sanitised, December 11, 1992.) LBJ Library, National Security File, Subject File, Outer Space, Volume 2. Box 37. 2 pages. Declassified at the request of the author.
3. P. Pesavento, "An examination of rumoured launch failures in the Soviet manned program. Part 1: Voskhod/1966", JBIS, 43 (9), pp.379-382, 1990.
4. Joint Publication Research Service. Science & Technology, Central Eurasia: Space. Graphic: "Space Program Expenditures in the USSR and United States". JPRS-USP-92-004, 10 June 1992. p.88.

Preparations for Soviet

The N-1 Rocket Programme

ALEXANDER YASINSKY
St Petersburg, Russia

In the February 1993 issue of *Spaceflight* (p.44) Daniel A. Lebedev wrote about the N-1 launches and the different types of booster compartments involved. I am able to add some more detailed information about the N-1 first-stage alterations.

The lack of a first-stage ground test facility meant that the Soviets had to improve the launch vehicle design on the basis of results from actual flights.

During the study of results from the first N-1 launch (the full booster serial number was V15003D), it was discovered that very intense heat occurred in the aft compartment resulting in a fire and shutting down the engines because of a short circuit in the control system KORD. Therefore the KORD system equipment was moved from the aft compartment into the intertank section (on the next booster). Also ventilation openings were made below the fuel pipeline covers in order to inject external air into the inside compartment.

The second launch of N-1 lasted only a few seconds and it has been described by Daniel Lebedev [1].

During the third launch the six reaction control engines at the base of the rocket could not cope with the very high rotation rate of the launcher about its vertical axis and it was destroyed. After this failure the first-stage design underwent most extensive alterations, especially to its shape.

First of all the conical skirt of the engine compartment was removed. Previously the conical skirt was thought to act as a stabiliser. However, it turned out to be a very bad stabiliser but a very good source of aerodynamic resistance. Therefore the lower part of the skirt (not the whole skirt as represented by Daniel Lebedev's sketch) was substituted by a cylindrical section (see the diagram on the opposite page). The aft compartment diameter was decreased from 16.9 to 15.8 metres. The first-stage engine nozzles were provided with aerodynamic shields (splashers) on their exterior side in order to protect them from the effect of the high velocity air stream. The six control engines at the base of the rocket were replaced by four powerful "rudder" engines installed inside "gondolas" on the cylindrical section of the skirt. The exterior

A group of boys from GIRN-1 with an N-1 fuel pipeline. In the distance are the rails of the N-1 crawler railway. (See the acknowledgement at the end of this article). *Antipov*

Chelomei's Lunar Programme

BY DANIEL A. LEBEDEV
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New information on the UR700, Chelomei's lunar booster, was presented at the BIS 7th Soviet Space Symposium held in June 1992. As a follow-up to this, Daniel Lebedev writes about the Chelomei design bureau and the manned lunar programme that it embarked upon. He says, "The information comes from different open sources and from private discussions at the Baikonur Cosmodrome".

Not only did the Chelomei design bureau develop automatic satellites, automatic space stations and the heavy booster "Proton", which enhanced its reputation, but also a manned lunar programme, about which much has remained unknown. The programme included two parts: the first a lunar flyby mission and the second a lunar landing mission.

In August 1964 the bureau began development of the spacecraft LK-1 which was intended to carry out a lunar flyby with a loop-shaped trajectory. The spacecraft consisted of three 'blocks': a crew-return capsule, an instrument module and a propulsion unit. The first two blocks resembled the US Gemini spacecraft and the last one was cylindrical. The LK-1 spacecraft was installed under the fairing atop of the booster with the launch escape system attached on top. The spacecraft had two solar arrays that would deploy after entering the lunar flyby orbit. It had aerodynamic properties and could be manoeuvred during reentry through the Earth's atmosphere. The LK-1 mass was relatively low and the crew capsule was small, but when a systems redesign later took place an additional armchair was installed for the second cosmonaut. It would have been very difficult for the crew members to have travelled in space for as long as a week in such a small pressurised volume, where to take off a spacesuit would have presented a problem.

The spacecraft was due to have been launched by the three-stage UR 500K "Proton" vehicle. It would have had a mass of about 16-17 tonnes when placed in LEO and would then have departed to the Moon using its own engine.

Chelomei planned for a mission during 1967, but at the end of 1965 the programme was abandoned. Korolev's L1 and N1-L3 programmes became the only ones for which finance was given.

However, Chelomei still continued his manned lunar programme, and his bureau began development of the manned lunar landing complex. On 16 November 1966 he presented a new concept, named LK-700, to the government. His idea was unconventional in that he suggested performing a direct flight to the Moon. According to him, such a type of mission would be safer than the N1-L3 or Apollo method as no docking operations would be needed.

The total fuelled mass of the spacecraft was around 130 tonnes, and this was 1.5 times heavier than that which the N1 booster was capable of delivering to LEO. Chelomei's bureau decided to use its own new heavy three-stage booster, which had characteristics similar to the US Saturn V vehicle. The design of the booster, named UR 700, had begun simultaneously with the UR 500K Proton programme. The booster had a block-type construction, each block being fully assembled at the plant and then delivered to the cosmodrome, where the booster would be assembled from its blocks, checked and launched. Launch preparations would take about one month.

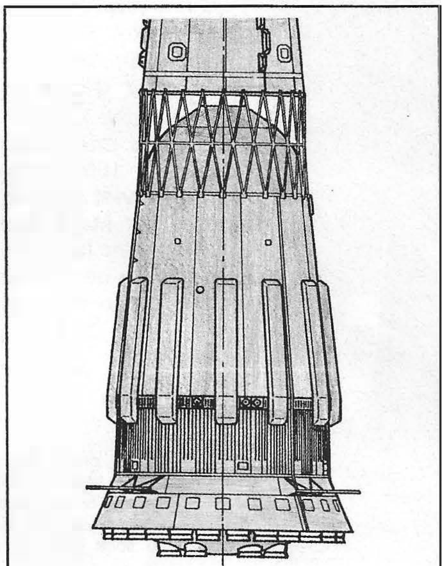
The lunar expedition complex, which

Manned Lunar Missions

fuel pipeline covers were sharpened at the top. A new additional conical section was put on the cylindrical part of the first stage (between the oxider tank and the conical skirt).

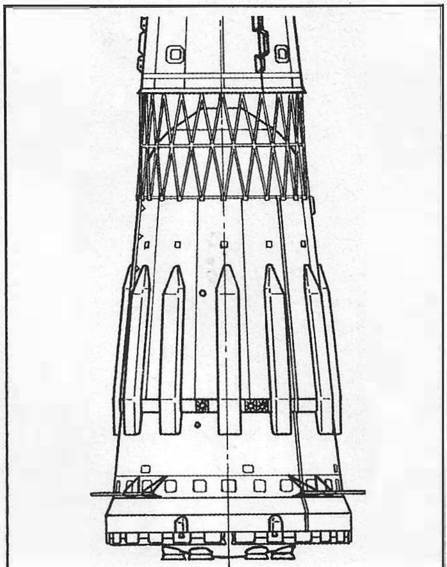
It should be noted that the fourth booster did not have "more recent (and more powerful) engines" as Lebedev writes. The booster number 7L had the same engines NK-15 as booster numbers 3L, 5L and 6L. The new engine NK-33 was to have been installed on the next booster (number 8L) which was never launched. Also filters were not installed in the tanks of the fourth booster either.

The launch vehicle colour was changed also. The first and second stages of the first N-1 (number 3L) were deep grey. A half of the third stage was deep grey too (from one side of the service tower) while the other half was white (from the opposite side). The payload section fairing was white too. With this colour arrangement the temperature inside the first and second stage compartments reached 60° C in summer and caused trouble when servicing the stages. Therefore booster numbers 5L and 6L were white with only a wide grey vertical stripe on the first and second stages. The launch vehicle number 7L was totally white, just as shown on page 46 (***Spaceflight***, February 1993).



The first stage of N-1 booster number 3L (the first launch) *Yasinsky (c) 1993*

The Vostok launcher was never used for testing lunar spacecraft components in elliptical orbit as Daniel Lebedev writes. The Soviet experimental lunar modules T2K were tested during launches of the 11A511L booster [2]. This was one of numerous versions of the "Soyuz" launcher [3]. Lunar orbital spacecraft were tested during launches of the Proton (8K82K) booster [3].



The first stage of N-1 booster number 7L (the fourth launch) *Yasinsky (c) 1993*

Acknowledgement

The author wishes to thank Igor Afanas'ev and also Vladimir Antipov and his group GIRN-1 from Leninsk. GIRN-1 stands for Gruppa Izuchenia Rakety N-1 (Study Group of the N-1 Rocket). This is a young schoolboys' team which is headed by Vladimir Antipov. They collect documents, photos and pieces of hardware on the history of the N-1/L-3 programme

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1. D.A. Lebedev, ***Spaceflight***, 1992, p.44.
2. V.M. Filin, "Memories about the Lunar Spaceship", "Kultura" Publishing Office, Moscow, 1992, p.72.
3. *Ibid.*, p.64.

was designed for the programme included four parts: a cylindrical acceleration block, a cylindrical deceleration block, the lunar-landing module and the crew-return capsule, which was attached atop of the lunar-landing module. The capsule was designed on the basis of the LK-1 spacecraft and there were places for two cosmonauts inside it. During the journey between Earth and Moon and back, the cosmonauts would occupy their places and leave only to go on to the lunar surface. The acceleration block was designed on the basis of the third stage of the Proton vehicle and had four engines. The deceleration block was created on the basis of the fourth stage of the Proton (or Block "D", that was also used in the N1-L3 programme). The maximum diameter of the complex was about four metres. All engines of the spacecraft and booster used nitrogen tetroxide and UDMH for propellants.

The mission scenario was as follows: the launch would be from the Baikonur cosmodrome and the spacecraft would enter LEO. After several circuits in Earth orbit the acceleration block would be activated increasing spacecraft velocity to 11 km per second and placing it on its way to the Moon. Soon thereafter the block would separate. All trajectory corrections and lunar orbit insertion manoeuvres would be performed by the deceleration block. This block would be used again to reduce the main part of the spacecraft's velocity during descent to the Moon. At an altitude of about 1-2 miles the block would separate and the spacecraft would make a touchdown on four landing legs using its own engines. (The spacecraft had low manoeuvrability and if touchdown was impossible due to the terrain or any other cause, it had only a few seconds in which to find a new place for touchdown. If this attempt became unsuccessful, the spacecraft must begin to return to lunar orbit using the same engine). The crew would spend approximately 48 hours on the Moon and then the spacecraft engines would ignite again, the support structure with landing legs would deploy and remain on the Moon and the spacecraft would lift off.

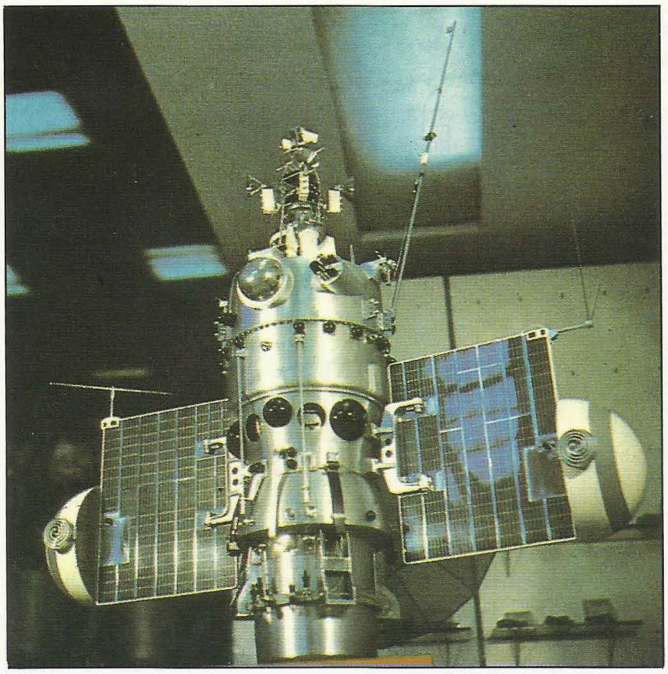
There were two possible mission profiles: the spacecraft would either enter low lunar orbit at first and then set off home or would set off home right away. All trajectory corrections during the return to Earth would be performed by the engines of the lunar module. (The module must have adequate fuel and its engines must be very reliable, because it would work during three stages of the mission, i.e. during lunar landing, during lift-off from the Moon and for insertion into the return orbit to Earth). The lunar landing module would separate from the crew-return capsule near the Earth and the capsule would reenter the atmosphere and land using parachutes.

According to Chelomei, if the government had given finance for this programme, the Soviets could have put a man on the Moon in 1968-69, before the Americans. Incidentally, the programme was supported by Glushko, who boycotted the N1-L3 programme. But money was not given and the programme was cancelled in 1970.

In the 1970s Chelomei presented a project, named MK 700, for travel to Mars. The crew for the mission would be either two or three with a mission duration of about two years. His bureau suggested the super-heavy booster UR 700 M with an estimated payload of about 250 tonnes for the programme, but due to finance, political and technical problems, the project remained only on paper.

Main sources of information

1. Private correspondence with V. Antipov, an engineer from the Baikonur Cosmodrome.
2. V. Afansiev, "Unknown spacecraft", *Znanje*, December 1991.
3. Kosmonautica Encyclopedia, M, 1985.



The Soviet Mars

Timothy Varfolomeyev has been looking into the history of both the Soviet Venus and Mars programmes and has previously written about the Venus Programme in *Spaceflight* (February 1993, pp. 42-43).

"It is now known", he says, "that work on the design of both Mars and Venus probes began simultaneously in the middle of 1958 when technical proposals were formulated in the Soviet Union for the development of interplanetary spacecraft. Mars spacecraft were designated Object M1. In the February issue (p.59) Peter Pesavento gave some recent information on the Mars mission attempts and I am now able to add some more pieces of information on this subject".

BY TIMOTHY VARFOLOMEYEV
St Petersburg, Russia

Left: The Mars 1 probe. Its appearance is very well known, but it is a strange fact that its umbrella high-gain antennae are directed in the opposite direction to that of the solar cells. Since the orbit of a Mars probe lies outside the Earth's orbit, the Sun and the Earth are on the same side of the spacecraft. So both the high-gain antenna and solar cells should look in the same direction. *Codr*

On 15 March 1960 a document "Designing spacecraft for Mars missions" was sanctioned by Academician Mstislav V. Keldysh [1], vice-President of the Academy of Sciences of the USSR.

According to this paper [2]:

"...Scientific equipment was to be installed on spacecraft in order to carry out the following scientific research:

(a) photography of the planet Mars at a distance of 5000-30,000 km, the still picture size being 50 x 150 mm and the object-glass focal length being 750 mm. Surface details of size 3-6 km were to be distinguishable on images received at an Earth station and the images were to cover one of the planet's poles;
(b) The CH emission lines in the infra-red band of the Martian spectrum were to be analysed in order to detect plant or other organic compounds on the surface of Mars;
(c) Research into the UV band of the Martian spectrum..."

So the main purpose of the first Mars probe was to flyby and photograph Mars while the purpose of the first Venus probe was to impact Venus as is now known.

In April 1960 the theoretical research "on predicting the accuracy of the trajectory of a moving M1 spacecraft" was completed by the Applied Mathematics Division of the Mathematical Institute of the Academy of Science of the USSR. The optimum launch date was established as 27 September 1960 [3]. Probe injection into the correct interplanetary trajectory from an intermediary Earth orbit required escape-stage engine ignition to take place over the Atlantic Ocean [4]. There was therefore a need to place a tracking and control station in the tropical South Atlantic. For this reason three merchant ships were fitted out as tracking ships; these were the ships "Il'Ichevsk", "Krasnodar" and "Dolinsk" [5]. In August 1960 they left their ports [5] and in September arrived at their charted positions. The ships were, however, kept waiting as during September the Soviets did not manage to launch a probe toward Mars. Numerous malfunctions delayed the launches several times. Finally the launches took place on 10 and 14 October 1960 [6] and both ended in failure. So the US intelligence sources that revealed the Soviet Mars attempts (of 1960) in September 1962 were right. As to the tracking ships, they came back to the Black Sea in November [7] without any results.

The Mars launch window of 1962 opened soon after the Venus window. As early as January 1961 preliminary values had been determined "for the correction of trajectories towards Venus and Mars in July-November 1962" [8]. Five variants of the Venus mission profile and three variants of the Mars mission profile were calculated. The last were as shown in Table 1 [9].

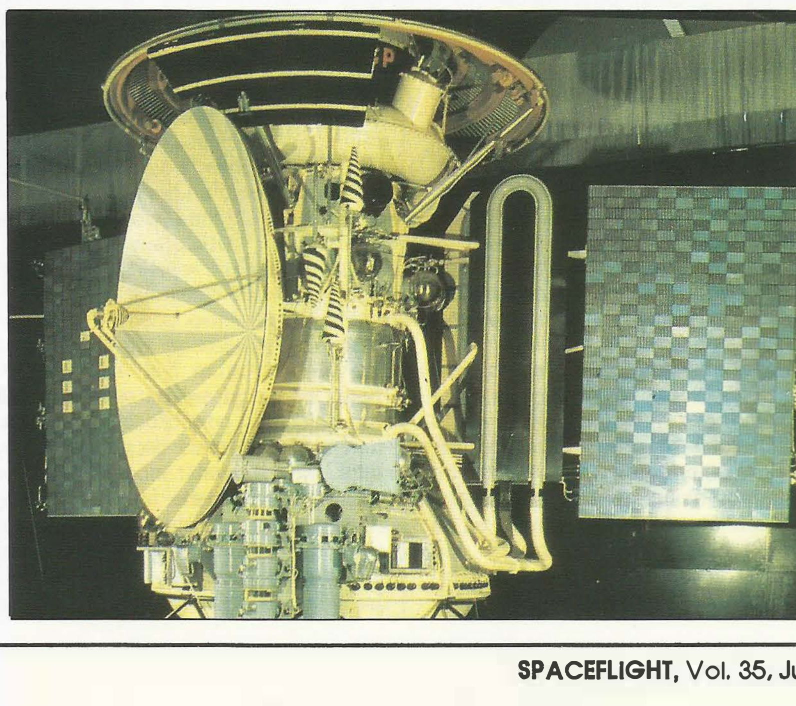
Two Mars versions of a unified Korolyov's "Object MV" (Object Mars-Venera) had been prepared for launch toward the Red Planet in 1962: MV-3 (landing) and MV-4 (flyby) while MV-1 and MV-2 were unsuccessful Venus probes of August/September 1962. As is widely known three launch attempts took place in 1962:

24 October	MV-4	flyby
1 November	MV-4	flyby
4 November	MV-3	landing

Only one Mars MV object left Earth orbit and was called Mars-1.

After designing a new test version of Object MV (named "Zond") and after Venus Zond failures of February/

A Mars spacecraft of the second generation. It is a true "Martian" spacecraft - the high-gain antenna dish and solar cells look in the same direction. *Markov*



Programme

March/April 1964 the turn of the Mars Zonds came in the summer of 1964. The first attempt of a Mars Zond technology test launch was made on 4 June 1964 toward the Moon in order to photograph its far side. But the probe never reached Earth orbit.

It is probable that two or even four spacecraft (as with the Venus MV Objects) had been prepared by then for launch toward Mars in the next window (in autumn 1964). But numerous malfunctions ruined all such plans and the Soviets managed to send only one probe to the vicinity of Mars on 30 November 1964. This MV object was called Zond-2 after it had been launched. It was the last of Korolyov's spacecraft to be launched toward Mars. In 1964-65, OKB-1 became busily involved with the N1-L3 programme and Korolyov had gave all lunar and interplanetary programmes to the G.N. Babakin design bureau.

Babakin took the decision to give up the iii-fated Korolyov Mars MV Object and to design a new generation of Mars spacecraft which weighed far more than the preceding ones and used the new powerful Proton launcher (8K82K) with the "Block D" stage to boost them into interplanetary orbit. These new spacecraft were not ready until early 1969 and therefore the Mars launch window of 1967 was missed.

What was the objective of the 1969 missions? Maybe it was to send spacecraft into Mars orbit as stated by Peter Pesavento (***Spaceflight***, February 1993, p.59). But as early as January 1963 M.V. Keldysh had sent a letter "About the design of primary spacecraft" to S. Korolyov [10] in which Lunokhod and "automatic descent modules for landing on Mars and Venus" [11] were listed as primary cases. Therefore the Mars-69 spacecraft more probably consisted of a flyby bus carrying a lander. Two launch attempts took place in 1969 and both ended in failure:

27 March	M-69
2 April (not 14 April)	M-69

The first failure was due to a Proton third-stage failure, the second was due to a malfunction immediately after first-stage engine ignition.

As to the next series of Mars launches it is suggested that the Soviet report about Mars-3's famous 20-second signal (purportedly coming from the lander on the Martian surface) was a lie. It is one of the myths invented by the Soviet official propaganda in order to cover up failure and to claim priority for the first Mars soft landing! Like the Mars-6 lander later on, the Mars-3 descent module could not make a soft landing because its horizontal velocity was too high.

Mars rovers were indeed installed on Mars-3 (and Mars-2 too) with the lander carrying the small "Marsokhod", but it can scarcely be called a "rover". It had no wheels at all and was like a "shoe on a sled". This "shoe" has been excellently described in *Planetary Report*, Vol. X, Number 4, July/August 1990, p.7.

It should be added that the Soviet Mars programme did not end after the Mars-4,-5,-6 and -7 missions. The point is that after the Luna-16 and -20 successes, the Soviet "top brass" imposed on Babakin's OKB Chief Designer Sergey S. Kryukov* in 1974 the ambitious project of a Mars Sample Return Mission! The test engineer of Babakin's bureau, Yuri Markov, recalls [12]:

> "...of course Sergey Serdgeyevich (Kryukov) understood the extraordinary complication of this project. He three into the development of this programme the best and most experienced people..."

But the project was not the only one being planned and other programmes were curtailed in favour of it. The launch of Lunokhod-3 (already built) was cancelled and the vehicle is now displayed at the OKB museum. Approval for work on Lunar-24 did not allow sufficient time and the preparations for a new Venus mission were not pursued with sufficient energy.

The realisation of such a project was beyond technical feasibility at that time. Considerable funds were expended without results and the project collapsed in the end. It resulted in the removal of S. Kryukov from his post in early December 1977 [13].

* S.S. Kryukov had been appointed on this post on 26 August 1971 after G.N. Babakin's death.

Table 2: Soviet Mars and Phobos programme summary.

Launch Date	Payload Code	Launch Vehicle	Mission	Official Designation
10 Oct 1960	M1	8K78	Mars flyby	-
14 Oct 1960	M1	8K78	Mars flyby	-
24 Oct 1962	2MV-4	8K78	Mars flyby	-
1 Nov 1962	2MV-4	8K78	Mars flyby	Mars-1
4 Nov 1962	2MV-3	8K78	Mars landing	-
4 Jun 1964	3MV	8K78	Technical test/Lunar flyby	-
30 Nov 1964	3MV-4A	8K78	Mars flyby	Zond-2
18 Jul 1965	3MV	8K78	Technical test/Lunar flyby	Zond-3
27 Mar 1969	M-69	8K82K	Mars landing	-
2 Apr 1969	M-69	8K82K	Mars landing	-
10 May 1971	M-71	8K82K	Mars orbit	Cosmos-419
19 May 1971	M-71	8K82K	Mars orbit/landing	Mars-2
28 May 1971	M-71	8K82K	Mars orbit/landing	Mars-3
21 Jul 1973	M-73	8K82K	Mars orbit	Mars-4
25 Jul 1973	M-73	8K82K	Mars orbit	Mars-5
5 Aug 1973	M-73	8K82K	Mars landing	Mars-6
9 Aug 1973	M-73	8K82K	Mars landing	Mars-7
7 Jul 1988	1F	8K82K	Mars orbit/Phobos flyby	Fobos-1
12 Jul 1988	1F	8K82K	Mars orbit/Phobos flyby	Fobos-2

Table 1: Mission profiles for the October-November 1962 launch window to Mars [9].

Variant	Launch day (1962)	Flight duration (days)	Impact day (1963)
1	16 October	220	24 May
2	31 October	225	13 June
3	16 November	224	28 June

References

1. M.V. Keldysh, The Selected Works, Rocket Technology and Cosmonautics, *"Nauka"* (Science) Publishing Office, Moscow, 1988, p.354.
2. *Ibid*, p.355.
3. *Ibid*, p.347.
4. B.A. Pokrovsky, "The Dawn" is Earth's Call Sign, *"Moskovsky Rabochiy"* (Moscow Worker) Publishing Office, Moscow, 1987, p.251.
5. *Ibid*, p.252.
6. The Star Trip of Yuri Gagarin (Documents on the first manned space flight), *Izvestia TsK KPSS* (monthly magazine of the Central Committee of the Communist Party of the Soviet Union), Moscow, No.5, (316), 1991, p.102.
7. B.A. Pokrovsky, p.253.
8. M.V. Keldysh, The Selected Works, p.406.
9. *Ibid*, p.407.
10. *Ibid*, p.475.
11. *Ibid*, p.476.
12. Y.M. Markov, Course toward Mars, *"Mashinostroyenie"* (Machine Building) Publishing Office, Moscow, 1989, p.56.
13. *Ibid*, p.57.

CORRECTIONS

Two corrections need to be made to my article "The Soviet Venus Programme" (***Spaceflight***, February 1993, pp.42-43). On page 42 it says that during the first Venus launch of 4 February 1961 "...the fourth stage separation mechanism failed, as it was not pressurised...". The words "separation mechanism" were mistranslated and should be replaced by "direct current transformer". In the second place the launch vehicle 8K78M (page 43) came into use later than 1963. The first 8K78M/Venera launch took place in 1969: it was Venera-5 but not Cosmos-21.

Seated for breakfast in the Operations and Checkout Building are the STS-55 flight crew. From left are Mission Specialist Charles J. Precourt; Payload Specialist Ulrich Walter; Payload Commander Jerry L. Ross; Mission Commander Steven R. Nagel; Pilot Terence "Tom" Henricks; Payload Specialist Hans W. Schlegel; and Mission Specialist Bernard A. Harris, Jr. *NASA*

Columbia Reaches '100th Day in Space': Shuttle Program Clocks Up 'One Year in Space'

Columbia was launched at 10:50 am EDT on 26 April on its German Spacelab D-2 mission. It was in October 1985, that the first German-USA mission, Spacelab D-1, carried 75 experiments into space. This mission had 88 experiments onboard. Being flown for the first time were ESA's Anthrorack and NASA's Baroreflex. As well as ESA and NASA, many European Universities participated in the scientific programme which was managed from the Spacelab Control Centre at Oberpfaffenhofen near Munich, Germany.

BY ROELOF SCHUILING
at the Kennedy Space Center

Monday April 26

After planned built-in-holds of 10 minutes at T-20 and T-9 minutes Columbia was launched on mission STS-55 at 10:50 am. The ascent was normal reaching main engine cutoff at about eight and a half minutes after liftoff. The external tank separated shortly afterwards and the manoeuvring engines fired about forty minutes into the mission to place Columbia in its planned orbit of approximately 160 nautical miles with an inclination angle of 28.45 degrees.

The seven-member crew was divided into two teams to facilitate round-the-clock operations. The "Red Team" consisted of mission specialists Bernard Harris and Charles Precourt together with payload specialist Hans Schlegel. The "Blue Team" was made up of mission commander Steve Nagel, pilot Tom Henricks, mission specialist Jerry Ross and payload specialist Ulrich Walter. Shortly after Columbia arrived on orbit the Red Team began an six-hour sleep period and were awakened at about 8:20 pm (KSC times) to begin their first full day of orbital operations and the Blue Team began their first sleep period at approximately 9:50 pm.

During the first several hours of orbital operations it was necessary to switch from the primary to the backup orbiter refrigerator/freezer when the primary unit which normally operates at -21 to -23 degrees Centigrade be-

Columbia Readied After On-Pad Abort

It is 7:30 am on April 26 and this time Columbia's flight crew are on their way to the launch pad for a successful launch at 10:50 am. *NASA*

Following the on-pad abort on Monday March 22 (reported in *Spaceflight*, May 1993, p.158), the immediate focus of operations at KSC was to place the Launch Pad in a safe condition. The Shuttle's external propellant tank was emptied and on the next day the Rotating Service Structure was replaced.

Two days after the abort, the anomaly which lead to the abort was successfully recreated and was confirmed as a check valve in the orbiter's main engine number 3. Overnight the valve was removed from the engine and flown to Rockwell's Canoga Park, California factory for disassembly and analysis. Managers decided not to remove the remaining check valves unless the disassembly showed it would be necessary. Instead, the three main engines on Columbia would be removed and replaced for the next launch attempt. Analysis of the check valve at the factory revealed that a small black non-metallic particle was the cause of the check valve's malfunction. The particle was believed to have come from a seal that was associated with support equipment used during the valve's manufacture.

Columbia's main engines were to be replaced by those slated for the upcoming launch of Endeavour on STS-57 which was then scheduled for late April. Preparations for the engine exchange were put into operation during the remainder of the week and the engine replacement began on March 29. The engine operations took place at the launch pad as it was not necessary to return the orbiter to its processing facility to do the exchange. During the week of March 29 to April 2, first main engine 2; then number 3, and then number 1 were replaced.

It was decided that an opportunity existed to launch the STS-56 mission before STS-55 and on March 30 it was announced that STS-55's new launch date would be planned for April 24. STS-56 would launch first with April 6 as the planned liftoff date.

The emphasis at the launch site shifted to the STS-56 launch and work on STS-55 proceeded at a lower level of effort. The countdown for STS-56 began on April 3 with a planned launch date of April 6; however STS-56's launch was cutoff at the T-11 seconds point (***Spaceflight***, June 1993, p.198). The STS-56 launch was delayed for two days and was finally launched successfully on April 8. Following

About the Crew

Commander ***Steven R. Nagel***, 47, Col., USAF, was selected as an astronaut in 1979. He first flew as a mission specialist on STS-51G in June 1985, a flight that deployed three commercial communications satellites. His next flight was as Pilot on STS-61A in November 1985, the first West German-United States cooperative Spacelab mission. His third flight was as Commander of STS-37 in April 1991, a mission that deployed NASA's Gamma Ray Observatory. ***Terence T. "Tom" Henricks***, 41, Col., USAF, who flew as pilot was selected as an astronaut in June 1985. His first space flight was as Pilot of STS-44 in November 1991, a Department of Defense-dedicated Shuttle flight that deployed the Defense Support Program satellite. ***Jerry L. Ross***, 45, Col., USAF, who was Mission Specialist 1 (MS1) was selected as an astronaut in May 1980. Ross' first flight was as a mission specialist on STS-61B in November 1985, a mission that deployed three commercial communications satellites and on which Ross performed two spacewalks to test space station construction methods. His next flight was STS-27 in December 1988, a classified Department of Defense-dedicated mission. His third flight was on STS-37 in April 1991, a mission that deployed NASA's Gamma Ray Observatory and on which Ross performed two spacewalks, one to unstick a balky antenna on the satellite and another to evaluate space station hardware. ***Charles J. Precourt,*** 37 Major, USAF who was Misson Specialist 2 (MS2) was selected as an astronaut in January 1990 and was making his first space flight. ***Bernard A. Harris, Jr.***, 36, MD, who was Mission Specialist 3 (MS3) was selected as an astronaut in January 1990. Harris was also making his first space flight. He joined NASA in 1987, serving as a clinical surgeon and flight surgeon at the Johnson Space Center until his selection as an astronaut. ***Ulrich Walter***, 38, who was Payload Specialist 1 (PS1) was nominated as a German astronaut by the German space agency in 1987 and made his first space flight. ***Hans William Schlegel***, 41, who was Payload Specialist 2 (PS2) was nominated as a German astronaut in 1987 and was making his first space flight.

gan warming up. The initial suspicions were that a blockage in the freon system might have occurred. These units are used to preserve blood and urine samples for some of the life sciences studies as well as biological samples from the biolabor experiments.

Tuesday April 27

Investigations began with the Anthrorack medical and weightlessness experiments. The first respiratory measurements were taken on payload specialist Walter.

Operations began with the Modular Optoelectric Multispectral Stereo camera, called MOMS, mounted on the aft exterior of the Spacelab. MOMS takes images of the Earth's surface that may assist mapping of the Earth's terrain with resolutions as low as a few yards.

A survey of the payload bay with the orbiter's television cameras revealed a loose insulation blanket on the airlock hatch. The situation was similar to that experienced on mission STS-40 and posed no problems for the Shuttle as long as controllers made sure that the area did not become too cold or too hot.

Columbia passed a major milestone during the afternoon (at 1 day 6 hours 18 minutes and 34 seconds Mission Elapsed Time) and reached its 100th day of flight time in space. Shortly thereafter, commander Steve Nagel congratulated the teams that built and maintain the orbiter.

As part of the Anthrorack experiments, Jerry Ross and Ulrich Walter performed exercises that measured and analysed their exhaled gases. They later worked with experiments to study the crystallisation of semi-conductor materials and the solidification of metallic alloys. Tom Henricks performed the first of a series of experiments to test the reflexes that maintain blood pressure.

The flight control team at Houston detected a small nitrogen leak in the crew cabin; however a trouble shooting procedure by crew members quickly isolated the leak in the common manifold area. The leak had no effect on the operations of the orbiter's water tanks; however, pressurised water was not available to allow the Universal Urine Monitoring System to completely clean itself. Flight controllers believed that a stuck accordion-shaped bellows in the waste tank caused a pressure build up that led to a nitrogen leak from the tank. Nitrogen is normally pumped into the tank so that the bellows contract and pressurise the fluid so that it can be expelled overboard for the orbiter.

The crew solved the wastewater tank problem by hooking up a contingency water collection bag in place of the tank. The bag was then dumped overboard from Columbia every few days. The crew also removed several floor panels to verify that the waste tank was damaged and leaking nitro-

the STS-56 launch, work on Columbia picked up in tempo and the new engines underwent Flight Readiness Tests and leak checks using helium gas.

The STS-56 launch success was also followed by extensive work in preparing Spacelab D2. The work was performed in three phases. The first, on April 8 following the launch on the adjacent pad, was to destow the experiment samples which had to be replaced or refurbished. This occupied 40 continuous hours with a team working inside the Spacelab laboratory module. Access to the module was through the Columbia's middeck area via a hoist which allowed personnel to be lowered down through the Spacelab access tunnel which was of course vertical while the orbiter was at the launch pad. In some cases experiment principal investigators were stationed in the launch tower structure and could exchange their experiment samples with fresh ones, the new samples being installed on the same day as the older ones were removed. Other items were removed and taken to the Hangar L support facility for refurbishment; a process that took approximately four days to complete.

Phase two concerned power maintenance which included operation and checkout of video recorders, experiment water pumps, a turbomolecular pump, two laser systems, and the biolabor and anthrorack experiment equipment. This was performed on April 12 and 13 and lasted 18 hours. Phase three began on Thursday April 15 and involved restowing experiments removed during phase one. This operation took about 12 hours.

By the weekend the STS-55 payload refurbishment was complete and the payload bay doors reclosed. On Sunday April 18 the Launch Pad 39A area was closed to non-essential personnel as the hazardous hypergolic propellant pressurisation and ordnance installation operations were accomplished. Preparations for picking up the countdown filled the next few days and at 4:00 pm on Wednesday April 21, the launch countdown restarted. Built-in-holds in the countdown would bring the clock to a planned T-0 at 10:52 am on Saturday April 24.

The countdown proceeded smoothly until the early morning before the planned launch. At that point countdown checks detected a possible faulty power supply on one of Columbia's Inertial Measurement Units. While placing Columbia's three units into their operational mode prior to the loading of the external propellant tank, data displayed by unit number 2 was symptomatic of an intermittent power supply. Although retests showed the unit to be operating properly, there was no assurance that the condition would not recur. The orbiter has three of these units which provide position and flight path information to the computers and the crew. All three must be operating to continue with a flight or to launch on a flight. At 4:30 am the decision was made to remove and replace the suspect Inertial Measurement Unit. The unit, which was located in the forward flight deck area, was replaced by technicians and an abbreviated countdown began on the evening of April 24 with a planned launch set for April 26 at 10:50 am.

The remainder of the countdown proceeded normally with built-in-holds at T-11 and T-6 hours on schedule and start of propellant tanking at about 2:30 am on Monday April 26. The planned T-3 hour hold lasted from 5:30 to 7:30 and the flight crew departed their quarters for the launch pad at about 7:30 am. By 9:30 am the crewmembers were in their liftoff positions and the hatch was closed.

STS-55: Spacelab D-2 Mission

gen. Flight controllers cutoff the nitrogen supply to the tank which remedied the nitrogen leak; however, the nitrogen system cutoff also cut pressure to the drinking water supply. The supply was usable but the pressure of the water as it came out of the galley was reduced somewhat and overboard water dumps were slower than normal. The problems with the waste tank did not interrupt any science activities and, with the back-up collection bag in place, the waste management system performed normally.

Wednesday April 28

As ground personnel reviewed the problems with the refrigerator/freezer and water systems to determine if fixes could be accomplished, science activities continued.

The flight controllers also worked on a list of instruments and systems which might be powered down when not in use so as to conserve the hydrogen and oxygen used by Columbia's fuel cells to provide electricity. Conservation of electrical power would allow Columbia to stay in orbit an extra day and provide additional time for scientific operations while still preserving the two weather contingency days held in reserve.

Payload activities continued to provide microgravity data as Jerry Ross and Ulrich Walter performed materials science and biological science experiments. In one experiment Walter used the fluid physics module work station to vibrate columns of water so that pressure sensors could determine the dynamics of the fluid actions. Ross worked with experiments that studied diffusion rates of molten salts and used the holographic laboratory for investigations of heat mass and particle transport.

During the evening the crew undertook repairs to the waste water tank as they isolated the tank from the pressurisation system for Columbia's water supply. The procedure required the crew to install a quick disconnect device to the waste tank's nitrogen line. After the device was in place the crew was able to pressurise the supply water tanks normally, thus returning the personnel hygiene and urine monitoring systems and the galley to their normal operating modes. The crew also verified the operation of the contingency waste water collection bag as they successfully performed a short waste water dump overboard from the orbiter.

Flight controllers noted a shut down of the orbiter's Flash Evaporator System (FES) when a dump of excess potable water was begun. The water dump was then completed using an exterior nozzle. The FES was the preferred method of dumping as it results in finer particles with less chance of contamination of astronomical or Earth observation instruments. However the nozzle water dumps can be made only if the orbiter is oriented to preclude the expelled water particles from entering the payload bay. Flight controllers felt the FES may have had ice in its core and could be restarted after flushing it with warm water. This procedure had been followed on several previous Shuttle flights.

Thursday April 29

The crew spent the night forging ahead with payload experiment activities in the German D2 Spacelab, including powering up the German Space Agency's robot arm. This robotic experiment, called ROTEX, investigated various methods of control of a robotic arm including remote controlled operations from the ground, operations which were controlled from the orbiter by the crew, totally automatic operations and other modes. The operations provided data for designers to use in evaluating how well they had incorporated the effects of weightlessness in the design of the joystick controller and the various joints and sensors of the arm.

Commander Steve Nagel and pilot Tom Henricks performed a trim burn of Columbia's engines to slightly adjust the spacecraft's orbit from a perigee of 160 to 158 nautical miles. Columbia had been gaining energy because of the small manoeuvres to point the MOMS scanner at targets on Earth for imaging purposes.

Ross and Walter completed respiratory tests and continued processing materials science experiments. The German payload control centre reported that a 20 mm gallium arsenide crystal, the largest even grown in space, had been grown on the mission.

In mid-morning the cooling system radiator panels which are located in the inner surface of the payload bay doors were deployed. The two forward panels on each payload bay door can be raised away for the door to provide additional heat rejection from both sides of the radiator panels. Radiators in the deployed position are about 30 percent more efficient because they reject heat from both sides. With the Flash Evaporator System shut down due to a suspected ice formation in the core, this supplemental cooling insured sufficient cooling capability for Spacelab experiment operations.

Tom Henricks tested the Crew Telesupport Experiment (CTE) which was designed to allow the crew to interact with ground controllers instantaneously using graphics. The equipment aboard the Columbia operated as planned but contact with controllers at the German payload control centre was not established.

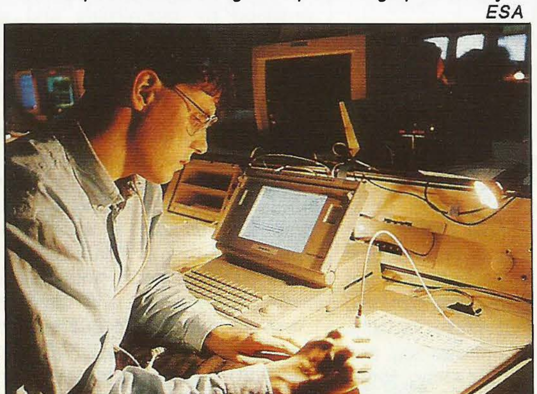
Mission commander Nagel was able to use the Shuttle's amateur radio equipment to make contact with the Russian space station Mir when both spacecraft were over Indonesia. The crews exchanged greetings for about one minute. During the contact, Mir was about 51 nautical miles above Columbia.

Friday April 30

Mission specialist Precourt successfully flushed Columbia's Flash Evaporator System with warm water in order to purge what was believed to be ice blocking its operation. The FES

Crew Telesupport Experiment (CTE)

CTE experiment featuring the pen-like graphics utility. *ESA*



Developed by ESA's Research and Development Centre (ESTEC), the Crew Telesupport Experiment (CTE) basically comprises an ordinary portable microcomputer and an optical disc player which are carried on board the Shuttle and are linked by a standard modem to identical equipment at the German Space Operations Centre via a voice channel. The optical disc has a pre-loaded database concerning some of the on board equipment for the D-2 mission. During flight, astronauts will use the CTE to call up on screen graphics relating to the other experiments on board or equipment being used, which are reproduced on the Operations Centre computer screen.

operated normally after the warm water flush procedure.

Laboratory work included monitoring the growth of cress plant roots to investigate how the roots, which have the ability to sense up and down, grow in an environment where those directions do not exist.

Flight controllers on the ground had detected an increase in oxygen flow in the cabin over a twelve hour period and initial concerns had focused on the possibility that a small leak had developed and the system was compensating for the leak. However, the actual cause was a variation in air temperature in the cabin.

Some particles were found to be floating in the sample chamber of a material processing experiment which uses a sample encased in aluminium oxide. When payload specialist Hans Schlegel removed the sample from the casing he noticed some of the material had flaked off and was floating in the experiment chamber. He closed the experiment door to prevent the particles from entering the Spacelab and ground analysis developed a procedure to insert a small vacuum cleaner into the chamber to clean out the particles.

Mission specialist Jerry Ross used the Holographic Optics Laboratory to study Marangoni convection which causes fluid currents to move from low pressure areas to high pressure areas. Scientists on the ground were able to follow the experiment and to watch as the convection currents developed.

Saturday May 1

Hans Schlegel became the first crewmember to have a saline solution injected into his body in an experiment to examine the natural fluid shifts that occur in orbit. The experiment like many of the life sciences investigations, was supplemented with data taken before and after the mission. About two litres of fluid were used and after the infusion the echocardiograph was used to study the responses of the heart, kidneys and femoral arteries to the replacement of the fluid. Blood samples and breathing evaluations are performed before and after such infusions. Shuttle astronauts have had to drink large quantities of water prior to their return from missions for several years as a method of replacing the lost fluid and easing their return to gravity environments. The infusion of fluid studies may also help validate whether bedrest studies done on Earth mimic weightless effects. The infused fluid disperses from the astronaut's body within 24 to 36 hours. Following the turnover to the Blue Team in the morning, Ulrich Walter became the second subject for the saline solution infusion.

Pilot Tom Henricks worked with the Crew Telesupport Experiment to send a message as the crew and ground controllers in Germany attempted to establish a link from Columbia to the payload control centre. Although successful in sending down a drawing with the system, investigators were not able to establish similar uplink from the ground to Columbia with the unit.

Overnight the Red Team continued saline solution infusion studies with Bernard Harris as the subject. Harris reported that his saline infusion was colder than body temperature as it had been removed from the warming tray for a period of time before use. Although room-temperature solutions pose no danger, and are administered routinely at room temperature on Earth, it was felt that the infusion of body-temperature solution would more closely mimic the body's reactions.

Sunday May 2

During the morning, mission managers decided to extend the STS-55 mission by an additional day and gather additional Spacelab data. The flight controllers and the crew had worked together over the preceding days to conserve electrical power and

Robotic Space Flight Scores a First

In working with the German Space Agency's robot arm, called ROTEX, on May 1 ground controllers in Germany reported a first for robotic space flight: the capture of a free floating target in space via control from Earth.

Anthrorak: A Human Physiology Laboratory

ESA's most spectacular contribution to the Spacelab D-2 mission was the Anthrorack facility for research into human physiology under weightlessness conditions. It carries 19 experiments mainly devoted to the cardiovascular and cardio-pulmonary systems, the metabolism and the endocrine system. One of this laboratory's firsts was its ability to take sets of measurements simultaneously, by means of a central computer managing all the experiments. This enables whole-body systems analysis to be performed which is an important advantage since, with only a few astronauts participating as test subjects, it is not often easy to compare and interpret the results obtained from different subjects in different flights.

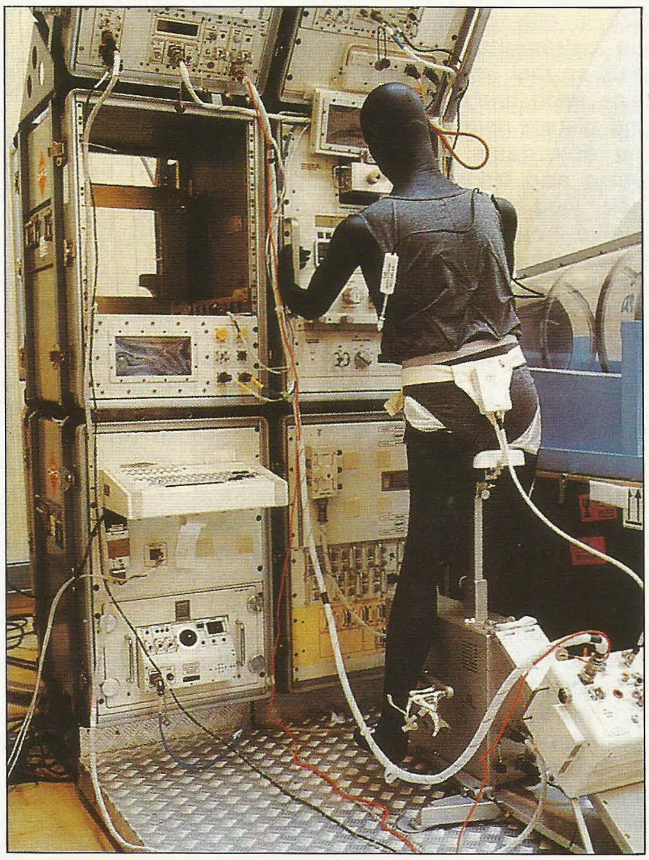
During the actual working days of the mission, the astronauts undergo, at pre-arranged intervals, a number of tests, during exercise (Anthrorack provides the bicycle ergometer shown in the photograph for this purpose) and at rest. Their blood pressure is taken and various special breathable gaseous mixtures are inhaled by them in order to study their distribution in the respiratory system and their effects on heart rate.

All results are transmitted in real time by telemetry, via three satellites and the NASA Johnson Space Center (JSC) at Houston, to the German DLR Control Centre at Oberpfaffenhofen, where the teams of scientists which developed the experiments are immediately able to analyse and record them. It is possible to forward voice commands and communications to Anthrorack from the DLR Command Centre by the same means.

Overall project responsibility lies with ESA's Research and Technology Centre, ESTEC, located in Noordwijk (the Netherlands). The operational aspects (training, assembly of experimental results and control of the laboratory in orbit) are being handled by the MUSC (Microgravity User Support Centre), at DLR in Cologne.

Anthrorack was developed under the prime contractorship of the French firm Aerospatiale with the participation of DASA-Raumfahrttechnik, OHB System and Panares (Germany), Logica and Verhaert (Belgium), BOC (UK), Amis (Denmark), Crisa (Spain), Matra Marconi (France-UK) and CIR (Switzerland).

The Anthrorack with a 'wired-up' dummy on the bicycle ergometer during laboratory testing. *ESA*



had accumulated an additional 25 hour margin on the cryogenic fuel cell reactants that produce electrical power.

Steve Nagel and Tom Henricks began their seventh working day in space with exercising on the Spacelab's bicycle ergometer. Jerry Ross, with assistance from Ulrich Walter, was the fourth, and final, crewmember to undergo an infusion of saline solution.

Columbia's systems continued to operate well and the Spacelab studies continued to operate on a 24 hour per day schedule. Flight controllers in an attempt to give each crew member a mid-mission break, scheduled a light work schedule for Nagel and Walter during the afternoon.

At about 4:45 pm the Houston Mission Control Center operations computer stopped processing data for about 15 minutes. However, no data was lost as all downlinked data is recorded. Analysis indicated that a peripheral computer was at fault.

Monday May 3

Hans Schlegel continued experiments with the ROTEX robotic experiment while wearing special goggles to provide a three-dimensional view from cameras mounted on the robot's gripping mechanism.

Schlegel and Harris, together with Ulrich Walter of the Blue Team closely monitored their meals and took a trace substance to study nitrogen in the human body in weightless conditions. Investigators want to understand the interaction between the observed loss of nitrogen and muscle function and size in microgravity. Before the flight the astronauts had monitored their diets so that investigators could determine each one's energy requirements and dietary composition. For the test, the astronauts ingested a special amino acid tracer that showed up in their blood and urine samples during a twelve hour period when they ate special meals providing specified amounts of nutrients.

The contingency waste bag that wastewater was flowing into was moved to an area under the middeck floor that had good ventilation so as to reduce odours from the bag.

Pilot Henricks and the ground controllers were able to use the Crew Telesupport equipment to transmit graphic images successfully both from and to Columbia for the first time. Previous experiments with the system had resulted in one-way transmission from Columbia of a single image, however this attempt was able to send three graphic messages to the orbiter and two down to the Earth.

Bernard Harris and Hans Schlegel started out on their twelve hour workshift without breakfast in order to perform a glucose experiment that studied how much insulin an astronaut's body produces. The two took a dose of glucose and then gave three blood samples taken over the next hour and a half, before having a late breakfast. Schlegel and Harris next performed a series of breathing evaluations designed to study the function of the human lung in space. Breathing measurements were made first at rest and then while exercising on a stationary bicycle.

Tuesday May 4

During the morning it was Jerry Ross and Walter Ulrich Walter who took part in the glucose studies. As before glucose dosage and periodic blood samples were followed by a late breakfast and later breathing studies.

Ground Link Lost

Mission control at Houston lost communications with Columbia for an hour and twenty minutes on May 4 after an errant command was sent to the spacecraft by controllers. The command caused the obiter's Ku-band antenna dish to lose track of the communications satellites it was using as the system was changing from a communications satellite over the Pacific ocean to one over the Atlantic. Once communications were lost, the flight controllers had to stand by for the crew to recognise the lack of communications. Following the realisation that the orbiter was no longer communicating with the ground, the crew had to perform a set of procedures to reestablish communications with Houston through the communications satellite system.

At 11:03 am Tom Henricks reported that the screen of the orbiter's number 4 CRT screen went blank. Recycling the CRT's power was not successful in restoring the unit and data system engineers on the ground began an analysis of the problem.

Later in the day Henricks performed the final stowage of the Crew Telesupport experiment for the mission.

Controllers were keeping a close eye on weather conditions predicted for the Kennedy Space Center's landing facility for the projected May 6 landing. The main concern was possible low clouds in the area.

During the evening, the Red Team began the science activities which had been developed for the additional day In orbit. Beginning at 10:00 pm the crew performed additional investigations with the MEDEA materials furnaces in development of gallium arsenide crystals for semiconductor research and with the Werkstofflabor devices to form liquid columns for fluid studies.

Wednesday May 5

Charles Precourt restowed the Columbia's radiators back in the latched position along the inside of the payload bay doors. The radiators had been deployed away for their stowed position earlier to provide extra cooling for the Shuttle and the Spacelab.

The flight control system was checked and this was followed by a hotfire test of the reaction control thruster system at 7:00 am. This verified that the steering jet and aerosurface controls were in good working order for the reentry and landing.

Henricks performed an intense-exercise period to study the effects of intense-exercise 18 to 24 hours before landing on cardiovascular fitness. Henricks had earlier completed a similar intense-exercise period on flight day three and the results of the two, together with postflight analysis of his condition, would be compared following the mission.

At 10:01:42 am the Space Shuttle programme passed a major milestone as the programme had then accumulated one year of total flight time since the Shuttle flights began **on April 12, 1981.**

During the afternoon, Blue Team members began stowing the Spacelab equipment in preparation for the landing the following morning. Later, the Red Team closed out and deactivated the D-2 Spacelab module.

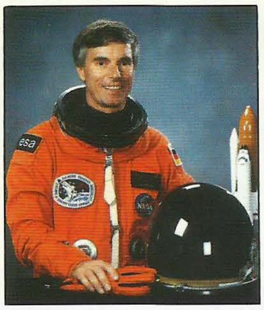
Thursday May 6

Columbia's landing had been planned for 9:03 am at the Kennedy Space Center. However, due to unacceptable weather predictions of low-level cloud coverage, mission managers elected to switch the landing to the Edwards Air Force Base in California. Columbia fired its manoeuvring engines to reduce its speed and landed at the California site at 10:30 am on May 6. Post landing inspections showed the orbiter to be in good shape following the ten-day mission.

Following the crew's departure for Houston, Columbia was readied for its ferry flight back to the Kennedy Space Center aboard a modified 747 aircraft. Columbia departed Edwards on Tuesday May 11 with a projected one night stopover and an arrival at Kennedy Space Center on May 12. Weather concerns, however, delayed the arrival of the Shuttle orbiter at Kennedy until Friday May 14.

With the one year in space mark passed on May 5, the Shuttle programme had 365 days, 23 hours and 28 minutes of accumulated flight time at landing time on May 6. During this period the Shuttles have carried to orbit 670 major fixed and deployable payloads totalling 822 tons, returning 636 payloads weighing 425 tons.

Representing only 5 percent of all United States space launches, Space Shuttles have carried 56 percent of US payloads to orbit and 44 percent of the cargo weight to orbit (based on non-classified Information). During their flights the Shuttles have also accumulated 96 days 13 hours of Spacelab science operations and 5.7 man-years in orbit.



Ulf Merbold. *NASA*

Selection of ESA Astronauts for Flights to Mir

BY ROLF H. SCHOEVAART
The Netherlands

Thomas Reiter. *ESA*

On May 7, 1993 ESA (the European Space Agency) announced the assignment of four ESA astronauts for the precursor flights to the Russian space station Mir-1 scheduled in 1994 and 1995.

Pedro Duque of Spain and **Ulf Merbold** of Germany will prepare for the first flight in September 1994 (mission 17), which will last 30 days. **Christer Fuglesang** of Sweden and **Thomas Reiter** also of Germany are the candidates for the second flight in August 1995 (mission 19), which will last 135 days and will include a spacewalk.

In August 1993 the four astronauts will start their training at Star City, near Moscow. About eight months before each mission ESA will nominate the astronaut chosen to fly and his back-up. The prime and back-up crews will then train in parallel. About a week before the mission, following the last medical examinations, the final crew selection will be made.

During these precursor flights the ESA astronauts will be able to gain and develop experience of manned space flight in preparation for future programmes in cooperation both with the USA and Russia. Furthermore a number of scientific experiments, connected with microgravity (life sciences, human physiology and materials science), will be carried out.

Duque, Fuglesang and Reiter were selected as ESA candidate astronauts in May 1992 and have no space flight experience so far. Merbold was selected in 1977 and flew as payload specialist in the first Spacelab mission on STS-9 in 1983. Two years later he was back-up payload specialist for STS-61A/Spacelab D-1. His second flight was on the Spacelab IML-1 mission (STS-42) in January 1992.

Originally there were *six* candidates for the ESA/Mir flights:

The fifth **Marianne Cheli-Merchez**, ESA candidate astronaut of Belgium, had already followed some cosmonaut training courses together with Pedro Duque and Christer Fuglesang in Star City for four weeks in October and November 1992. However, she decided to live in Houston with her husband Maurizio Cheli for two years and stood down from the selection for the flights to Mir. Cheli is also an ESA candidate astronaut (of Italy) and is training as a mission specialist at the NASA Johnson Space Center.

The final candidate, **Wubbo Ockels**, was rejected because of a minor medical problem. Ockels, ESA astronaut of the Netherlands, was alternate payload specialist for Ulf Merbold on STS-9. His only space flight so far was the highly successful STS-61A/Spacelab D-1 mission in 1985. It is not the first time that Dr Ockels' nomination for a space flight did not turn out well. One of the new safety rules after the Challenger accident (a maximum of seven crewmembers) prevented Ockels from flying on the second German Spacelab mission STS-55/D2. In October 1992 he was passed over for the Spacelab IML-2 flight planned for July 1994, although the ESA member states had unanimously supported his nomination at NASA Headquarters. (See ***Spaceflight***, December 1992, p.385 and May 1993, p.155).

From left to right: Pedro Duque, Christer Fuglesang and Marianne Cheli-Merchez in the Soyuz Simulator. *ESA*

Correspondence

Re-use of Gemini 2

Sir, In response to Peter O. Johnson's letter in ***Spaceflight***, June 1988, I took this photograph of Gemini 2. It resides at the Air Force Space Museum at Cape Canaveral Air Force Station. The cut out in the heat shield is not related to MOL, but was done to show the thermal control system under the shield. I have not found any photographs showing the actual tests of someone using the shield hatch. I suspect that the shield on display is from the first launch, and the shield from the second launch is in a warehouse. There is clearly no passage through the shield as Gemini 2 is currently displayed.

SCOTT HEDRICK
Florida, USA

From Peter O. Johnson's June 1988 letter:
Although both of Gemini 2's missions were unmanned, it was certainly the first re-use of a manned (or man-rated) spacecraft.

The first flight of Gemini 2 occurred on February 19, 1965. It was a suborbital systems test. The spacecraft was a complete production Gemini craft, fitted wtih crew simulators in the ejection seats. These simulators tested the environmental and communications systems. The flight was a success.

Gemini 2's second mission was on November 3, 1966, as part of the Air Force's Manned Orbital Laboratory. The spacecraft was modified to include a hatch in the heat shield, allowing access to the MOL itself. The goals of the suborbital flight were to test the integrity of the modified heat shield and to prove the Titan IIIC launch vehicle. Both goals were fulfilled, but as events turned out, it was the first and only flight of MOL.

Does anyone know what Gemini 2's ultimate fate was?

The Gemini 2 capsule on display at Spaceport USA, at the Kennedy Space Center. There is no hatch in the portion of the bulkhead visible through the heat shield hole. The capsule is displayed behind a barier and the capsule itself is encased in a plastic cover.

'Space' in Music

Public support for Space has been in short supply in recent years, but towards the end of 1992 an unlikely source was identified - the Pop Industry! Tasmin Archer's 'Sleeping Satellite' became the subject of Correspondence and of Mark Hempsell's article in the December 1992 issue of *Spaceflight*. In subsequent issues of *Spaceflight*, readers wrote about their wide-ranging interests in the Space-Music relationship. As one correspondent said early on, "Space consciousness is alive, well and here to stay in contemporary music". Here is a further selection of readers' letters that confirm the point:

Space-Related Music

Sir, I have read with interest the various letters relating to the above. I have looked though my collection of LP's and found several tracks by various artists. These are: 2000 Light Years from Home *The Rolling Stones,* Moonroof *Sky,* Law of The Universe *Cliff Richard,* Starmaker *Ashford and Simpson,* Aurora *The Carpenters*

In addition there is the excellent soundtrack LP entitled "2001 - A Space Odyssey" taken from the film of the same name.

W.E. DEWERSON
Essex, UK
Member of the BIS

Space 'Filk' Music

Sir, I am writing concerning the recent discussion of Space-related music and songs in the December, January and March issues.

There are a large number of such songs which have been produced on an amateur basis by science-fiction fans, as part of what is known as 'filk' music (the name originated as a typographical error for folk music). This is, broadly, songs sung by fans at science-fiction conventions, including dedicated filk conventions (these are common in the USA and have run for the past five years in the UK).

The subject matter tends to be very wide ranging but includes: songs inspired by science-fiction books and films (and in particular Star Trek), fictional 'folk songs' which might be sung by future astronauts, songs about the space programme and promoting space travel and songs about actual historical incidents.

Among the latter are in particular: Leslie Fish's "Hope Eyrie" about the Apollo 11 landing and the Challenger Memorial tape - a cassette tape of songs sung at a special session at a filk convention held in early March 1986.

I understand that Frank Haye's song about a cosmologist searching for "The Hole in the Middle of it All" was broadcast as a wake-up song to astronauts on the Hubble launch mission.

I have also heard of filk singing in Australia, Germany, Russia and Scandinavia.

C.R. CULPIN FBIS
London, UK

Space Recordings

Sir, As a long time collector of space recordings, I have found the recent, and hopefully continuing, correspondence regarding space related music to be most interesting. Consequently, I would like to add a few titles of my own, despite somewhat tenuous space links in some instances.

Sputnik, Explorer and Vanguard were launched during Donald Fagin's "I.G.Y."; Louis Prima went "Beep, Beep" although "They Said It Couldn't Be Done" according to Frankie Ford. Skip Stanley had a "Satellite Baby" and Jerry Engler a "Crazy Satellite Girl"; Gary 'U.S.' Bonds said "We'll Rock & Roll To The Satellite Stroll".

In 1962 The Tornadoes went into orbit with "Telstar" (along with The Shadows, Ventures, Apollo 100 et al); The Ventures later flew on "Gemini", "Apollo 11", "Skylab" and "Columbia"; In 1973 Bob Rowe flew a different "Skylab" whilst in 1979 Sammy Hagar lived aboard "Space Station No. 5" as did Montrose in 1980. Adam and the Ants crewed "Apollo 9" in 1984 and Don Spencer piloted "Fireball XL-5" ('I wish I was a spaceman, the fastest man alive. I'd travel round the Universe in Fireball XL-5'). The Ventures took part in a "Solar Race" against Blondie's "Dragonfly".

Jackie Lowell took a "Rocket Trip" in Phil Bennet and The Sparkletones' "Rocket Ship". David Bowie's Major Tom ran into difficulties in "Space Oddity" but returned to Earth in Peter Schilling's "Major Tom (Coming Home)", despite Schilling having an "Error In The System"; Bowie buried Major Tom in "Ashes To Ashes".

The Busters' "Astronauts" flew Chris Kenner's "Rocket To The Moon", overtaking Freddie Cannon who was just "Walking To The Moon". The Police took giant steps "Walking On The Moon" and Bill Haley had a "Rocking Chair On The Moon" years before Val Doonican; Max Bygraves' "Fings Ain't What They Used To Be" had monkeys flying 'round it and prophesied 'we'll be up there with 'em soon', correctly it seems as Jonathan King claimed, "Everyone's Gone To The Moon". Floyd Robinson wondered "If The Man In The Moon Ain't A Lady".

Chris de Burgh's "Spaceman Came Travelling" with David Bowie's "Starman", Elton John's "Rocket Man" and The Tornadoes' "Globe Trotter". "I Lost My Heart To A Starship Trooper" exclaimed Sarah Brightman; Dee D. Jackson met a "Meteor Man"; Connie Francis dated a "Robot Man"; and David Bowie was "Loving The Alien".

Paul McCartney visited "Venus & Mars" and Manfred Mann journeyed to Jupiter (in a vocal version of Holst's composition entitled "Joy Bringer"); Jimi Hendrix orbited the "Third Stone From The Sun" (and probably still does). John Denver was "Flying For Me" (Hoping to fly for himself); Buchannan & Goodman flew "Flying Saucers".

Using Pink Floyd's "Interstellar Overdrive", The Beatles flew "Across The Universe" as did The Rolling Stones, who were at least "2000 Light Years From Home" and The Ventures, who made a "Journey To The Stars". "We Must Believe In Magic", remarked Crystal Gayle on her way to Alpha Centauri; Clannad got as far as "Sirius". The Ventures went on a "Star Trek" and The Firm went "Startrekkin'"; Brian May and Friends were members of "Star Fleet".

Klaatu and The Carpenters were "Calling Occupants of Interplanetary Craft" (Incidentally, this is the record with the longest title to chart in the UK - Its full title being "Calling Occupants Of Interplanetary Craft (The Recognised Anthem Of World Contact Day)"); The Rah Band received "Messages From The Stars" and The Moody Blues heard "Voices In The Sky" when Kate Bush said "Hello Earth". Bowie asked is there "Life on Mars".

Billy Lee Riley was doing the "Flying Saucers Rock & Roll" while Don Lang did the "Red Planet Rock" and The Randells went to "The Martian Hop"; The Martians returned the visit, coming to Earth in Jeff Wayne's "Eve Of The War". Meco were in "Star Wars" and Big Daddy went on musical manoeuvres in "Starwars"; The Ventures fought the "War Of The Satellites".

Looking to the future, the Cues were hoping to reach "Destination 2165" until Peter Schilling evacuated the Earth in "The Noah Plan", possibly as a response to Sammy Hagar's warning,. "This Planet's On Fire".

The Moon has been seen over Kentucky, Manakora and Bourbon Street, casting Cat Stevens' "Moon Shadow" and Mike Oldfield's "Moonlight Shadow". It has been variously described as being yellow, green and blue, prompting Carl Mann to remark "Look At That Moon".

Stars have fallen on Alabama and Stockton; Little Eva wanted to swing on one and Perry Como got them in his eyes five years before trying to catch a falling one.

and Song

Bill Haley's Comets took their name from Halley's Comet of course which, during its 1985/86 apparition, inspired Chas and Dave to write "Halley's Comet". The irrepressible Patrick Moore, on Xylophone and accompanied by The Ever Ready Brass, recorded "Halley's Comet March".

The Rank Concert Orchestra conducted by Ed Welch released the album "Moonshot" in 1979 to mark the tenth anniversary of the Apollo 11 mission. Its 15 orchestral pieces are interspersed with dialogue from the mission.

The Ventures made two albums on a space flight theme: the classic 1963 release "(The) Ventures In Space" and the 1983 "NASA's 25th Anniversary Commemorative Album".

Jeff Wayne, Rick Wakeman and Kevin Peek combined on the album "Beyond The Planets", a collection of eleven tracks.

Astronauts Brewster Shaw, Jim Wetherbee, Robert 'Hoot' Gibson and George 'Pinky' Nelson formed the group Max-Q. Steve Hawley may later have joined the band on keyboards. To the best of my knowledge, they have never released anything on record and play mostly at Astronaut Office parties. Their repertoire includes Bob Seger's "Shame On The Moon".

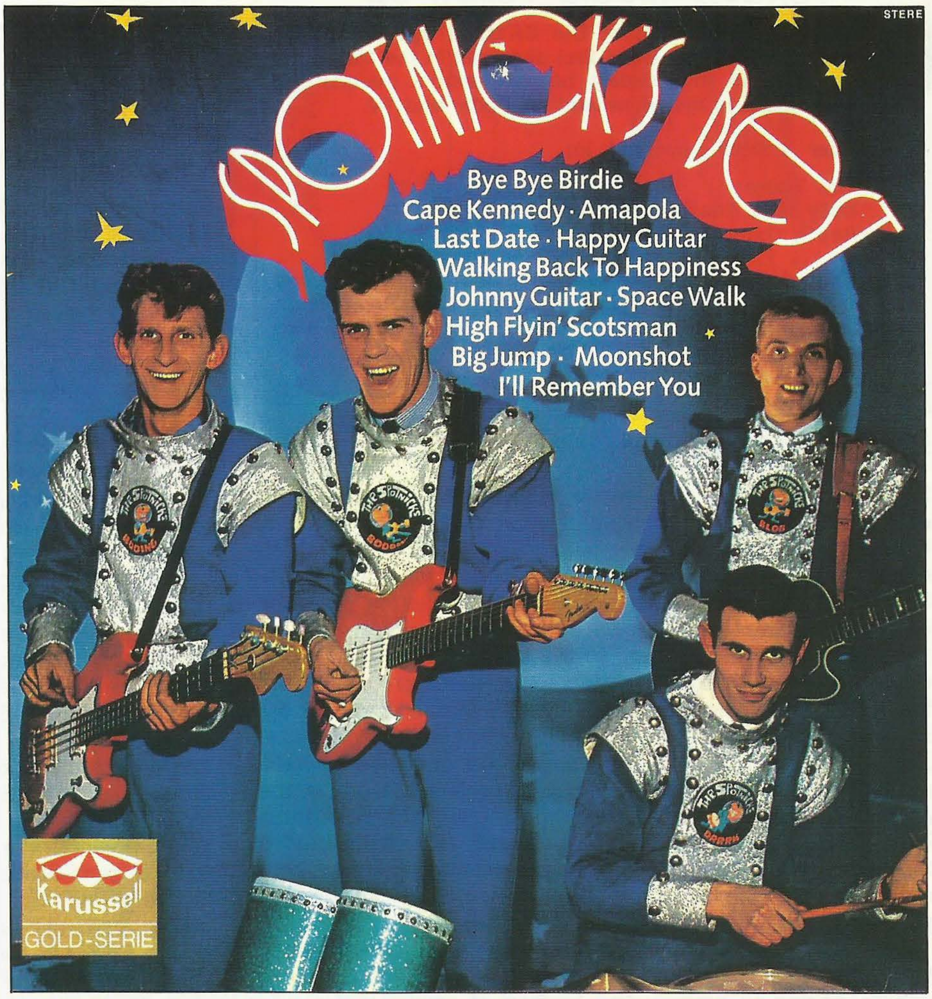
Astronaut Ron McNair, for whom Jean-Michel Jarre's "Last Rendez-Vous (Ron's Piece)" was composed, played saxophone in a band known as Contraband. "Ron's Piece" would have been the first musical piece to be played and recorded in space.

Sally Ride is honoured in The Ventures', "Theme For Sally".

A favourite recording of many astronauts is Crosby, Stills, Nash and Young's "Southern Cross".

Martin Cresdee (***Spaceflight***, January 1993) made reference to the Voyager record which carries, in addition to its music, 116 pictures of Earth and greetings in 55 past and present languages. Carl Sagan's excellent book, "Murmurs of Earth: The Voyager Interstellar Record" (ISBN 0 340 24423 2), tells the full story. The twenty-seven musical selections cover the range from Bach's "Brandenberg Concerto No. 2", "Gavotte en Rondo" and "The Well Tempered Clavier" via Louis Armstrong's "Melancholy Blues" and Blind Willie Johnson's "Dark Was The Night" to a Pygmy girls' initiation song from Zaire and a Navajo Indian night chant. The record was cut at 16 2/3 rpm and carries the fitting dedication, engraved between the lead out grooves, "To the makers of music - all worlds, all times".

MIKE HARBOUR
London, SE18



Space Music

"The Spotnicks": Russian Space Songs

Sir, Since many readers apparently like to know more about space-related music (see Correspondence pages of five recent issues) the following information may be of interest.

First, I would like to draw attention to "the Spotnicks", a Swedish pop group which was active in the years 1962-1965 when the era of manned space flight had just started. On stage, the Spotnicks wore spacesuits while their guitars and amplifiers were not connected by leads but, more appropriately, by radio waves - an innovation at that time.

The Spotnicks toured the UK twice, recorded several albums (one was called "Out-a Space") and even scored a couple of hits. Their repertoire included titles like Rocket Man, Space Creatures, Moonshot, Space Party and Space Ship Rendez-Vous. I enclose a photo of the Spotnicks dressed in spacesuits (without helmets though).

Second, referring to a letter from Thomas Gangale in the March 1993 issue of ***Spaceflight***, I can confirm that the Russians have their own space songs. On 29 December 1992, during the launch party of Cosmos-2229 (aka Bion-10), the Plesetsk personnel performed a song called "Na dikikh planetakh dalekohmechty, ostanutsya nashi sledy" which translates approximately into "Our imprints are left on wild planets of a distant dream". This song stems from the time of Gagarin's flight and is widely known in Russia. It was originally recorded by a Moscow singer called Vladimir Troshin.

Another well-known Russian space song is "Znayete, kakim on parnem byl", about Yuri Gagarin. The title means "Do you now what fellow he was". The song was written by I.A. Pakhmutova (music) and N. Dobronravov (lyrics) and was recorded by the late Yuri Gulyaev, an opera singer.

A last piece of information: apart from "Mr Spaceman", the Byrds have recorded the following space songs: "Space Odyssey", "CTA-102" (a tribute to a quasar!), and , in 1969, "Armstrong, Aldrin & Collins".

RENÉ DEMETS
Amsterdam, The Netherlands

Spaceflight's SKYLON Article Attracts Media Follow-Up

The technical description of the SKYLON spaceplane by Richard Varvill and Alan Bond first appeared in the May issue of *Spaceflight* and immediately became source material for follow-up reports in the press and on Radio and TV.

Newspaper articles appeared in:

The Times	**April 29**
Daily Mail, The Sun, Oxford Mail	**April 30**
South Oxfordshire Courier	**May 6**

Radio Oxford did a live interview with Alan on April 29 and Central TV filmed Alan and broadcast the SKYLON story on lunch-time and evening news on April 30. Coverage was also given on Radio 4, 'Science Now' on May 1.

Media information courtesy of Diane L. Holmes

SKYLON Technology

Sir, I am replying to the articles in ***Spaceflight*** (May 1993) on the research which has been done by Mr Alan bond on the air-breathing rocket engines, the RB545 and SABRE respectively. Mr Bond has designed a new winged launcher SKYLON about which I have a number of queries which he or someone else might be able to answer.

My first query is in regard to the shape of the vehicle. My elementary knowledge of hypersonic aerothermodynamics tells me that for the avoidance of high temperatures at the stagnation regions of a hypersonic vehicle (e.g. at the nose and wing leading edges) they should be designed to have as large radii as aerodynamically possible. Basically the SKYLON looks too pointed for reentry and a similar doubt exists as regards to the engine locations. This is the reason the blunt nosed Space shuttle which enters the atmosphere at hypersonic speeds looks so different from the sharply pointed supersonic transport Concorde.

My second query is in regard to using a horizontal launch technique. Using the figures given in the article the SKYLON vehicle seems to have a fuel fraction of around 80%. It is generally accepted that for an aircraft taking off under its own power the maximum fuel fraction possible is about 70%. For example the highest fuel fraction ever achieved was that of the Rutan Voyager, used for the record breaking non-stop unrefuelled around the world flight, which had a fuel fraction of 72%. I require convincing as to the feasibility of a horizontal launch even with a rocket assisted take-off. Surely it would be more feasible to launch a winged SSTO vehicle vertically, especially as the RB545 is capable of starting at zero airspeed. A winged vertically launched SSTO concept (whose ancestry can be trace back to the early winged-V2 experiments during World War 2) was proposed by a team led by Boeing as one of the unsuccessful SDIO bids. It was eventually beaten by the McDonnell Douglas Delta Clipper design. This vertical launch method should be feasible at the 80% fuel fraction of SKYLON. It should also be considered whether the wings could be done away with altogether as with Delta Clipper with the vehicle making a powered vertical landing.

My final point is to make a suggestion as to possible future research and commercial possibilities for the RB545 and SABRE rocket engines. Has Alan Bond considered scaling down either engine for use with small expendable winged launcher vehicles such as the Pegasus vehicle developed by the Orbital Sciences Corporation? I know that at present they are pursuing research into extending the performance of the vehicle by the addition of turbo-jet engines for the atmospheric part of the flight.

The scaled down air-breathing rocket engine should allow a single stage Pegasus vehicle to launch payloads into orbit having been air-dropped in the usual way. Initially the vehicle would be expendable but it could be developed into a completely reusable spacecraft. If it did prove feasible then this vehicle would provide the ideal forerunner to any full sized proper SSTO spaceplane and then at least Alan's engine would at last get a chance to fly.

DAVID M. TODD
Middlesex, UK

The SKYLON Technology

A Response to Readers' letters from Alan Bond

We are grateful for the opportunity to comment on the constructive points raised in correspondence by J.G. Pearsall and D.M. Todd.

Our paper in ***Spaceflight*** (May 1993) was intended as a broad technical description of the SKYLON vehicle and commercial issues were deliberately not discussed in any detail. Here we will address the technical comments first and the commercial/operational aspects later.

* * *

Hypersonic vehicles should, for aerodynamic reasons, be as fine as possible with sharp leading edges in order to minimise drag. However, if passive cooling (i.e. radiative) is to be employed, one solution is to accept increased drag by blunting leading surfaces in order to create a subsonic region and a stagnation point behind a detached shock. This is acceptable on a re-entry vehicle such as the Shuttle or Apollo capsule since the drag is largely irrelevant. However, for ballistic missile reentry vehicles with ablative cooling, and even the X-15 these options were not acceptable and fine leading edges were employed. On SKYLON we are still addressing the cooling of the leading surfaces. This is not so severe as STS since reentry occurs at a considerably higher altitude but it is aggravated by shock-shock interaction problems. We may ultimately have to resort to some form of semi-active cooling (e.g. heat pipes) or active cooling (e.g. steam). The foreplanes already employ actively cooled bearings and leading edges during re-entry.

The SKYLON vehicle is not a high lift/drag cruise aircraft but follows a continuously accelerating ascent with emphasis on minimal structure weight. This results in an optimum wing which is very small and light compared to a normal aircraft, and also results in the use of small engines compared to vertical ascent rockets. These factors result in a high fuel fraction compared to normal terrestrial aircraft, but modest compared to rockets.

Another factor which should not be overlooked is the scale of the SKYLON vehicle which has a total volume of 1700 m^3 and a mass of 275 tonnes. At this size problems of 'minimum gauge' are less important than on a vehicle such as 'Voyager' and help the achievements of a high propellant fraction.

* * *

Our investigations of transport costs lead us to dismiss any intermediate solutions, such as small launchers or semi-expendable vehicles, as having no long term cost merit. The development cost of a vehicle or engine system increases only relatively slowly with size (approximately to the half power of scale) and this is true for launch operation costs also, rendering small vehicles uncompetitive. In our view regular, efficient access to space is long overdue and we would not support schemes delaying this capability any longer.

As far as we are aware, SKYLON is the *only* spaceplane study which has been based on a true economic analysis,

Spaceplane and Economics

and Richard Varvill of Reaction Engines Limited

involving an aircraft sales consultant and data on world economics supplied by the IMF. The marketing and sales strategy of Reaction Engines Ltd must, for commercial reasons, remain confidential but broadly speaking the use of simple traffic models is dismissed since they imply the continuation of current monopolistic launcher practices. We believe that there is a worldwide market for launch vehicles, as there is for aircraft, and this has been supported by analysis. We expect to see eventually any nation which can afford their own vehicles flying their own payloads to orbit.

Despite the comments by Pearsall regarding cheap multistage launchers, we must, with respect, disagree. The main factor which fails to be appreciated by the advocates of cheap expendable launchers, whether ex-missiles or purpose designed, is the impact of quality assurance, and testing. For historical reasons, space is the *only* transport arena where there are true advocates for expendable transport. We fail to see why this exception should exist when the technology exists to produce reusable machines as in other transportation fields.

* * *

We presented our summary of desirable and undesirable characteristic of spaceplanes as a general comment, not just on SKYLON. Delta Clipper for example, which we regard as a spaceplane, has many of the features we would advocate, but we are reserved about the ability of Delta Clipper to achieve its re-entry performance, and also its environmental impact.

There is a view that rocket engine noise is irrelevant and that one can always choose a remote launch site. However, we feel that if space develops into a true economic arena, population will follow the launch site wherever it goes and it will develop into an inhabited area. Thus engine noise *is* important to a successful transport system. Winged vehicles have small engines as noted above, with consequent noise reduction.

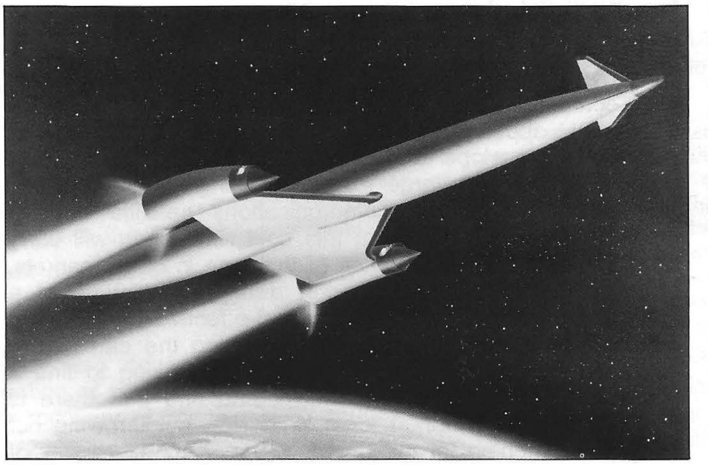
* * *

Finally, a note on investment. The heyday of government support around the world is gone. It no longer has political capital. Space will only develop if it has economic returns, whatever form they may be in. Reaction Engines Ltd began seeking private investment in 1988 and now has more experience of what features attract investment in launch vehicles than any other aerospace group that we know.

We would not disagree in principle with Pearsall's penultimate comments, but we do disagree with his assessment of the potential market and potential investment situation. We believe we know these very well and SKYLON has been determined to meet just these requirements. Obviously, in our view with the technology known to us, SKYLON is the only vehicle which we have been able to conceive which can satisfy the economic drives upon it. We hope that we will be allowed to prove these statements in practice.

SKYLON Economics

Sir, I would like to comment on the article on SKYLON: A Key Element of a Future Space Transportation System. I feel that the authors are over confident of the advantages of air breathing single stage spaceplanes on two counts:



SKYLON, a single-stage-to-orbit spaceplane.

(1) Most of the advantages they ascribe to their design are not inherent to it but are features of *any* good design and conversely disadvantages they ascribe to other designs are not inherent to them but have been the case in specific examples of these other designs;

(2) The role of the market in determining an effective solution appears to have been ignored.

Dealing with the points as they appear in the section headed "What Should a Spaceplane be Like?":

1. The increased costs of multistage systems are up to a point a function of design. Historical costs may be misleading on this point as for political reasons major launch vehicles were built on a "fair shares for all" basis which meant that different contractors were responsible for different stages resulting in duplication and incompatibility.
   A multistage system may still yield a lower specific launch cost if the payload fraction is sufficiently high relative to a SSTO.
2. If a vehicle has boosters, disposable or not, then it is not an SSTO and must be considered as a multistage vehicle.
   Reusability is not a feature exclusive to spaceplanes. Reducing the element of specific cost due to vehicle production by charging it over more uses is of itself just an accounting device. It is meaningless unless you can actually achieve the desired reusability at a cost lower than the marginal cost of a new vehicle, this remains to be demonstrated for any reusable vehicle. The important point is that it is not just a technical issue - it is a function of demand i.e. have you got enough payload to use the required number of relaunches.
3. Reusability and high mission assurance surely mean that the reliability and quality assurance standards of the unpiloted vehicle are close to if not greater than presently accepted man rating standards. This applies to any design and implies that the development "premium" of man rating would not be a major design determinant. Autonomy is not exclusive to spaceplanes it is a desirable feature which can be incorporated into any design.
4. None of the advantages claimed for spaceplanes is actually exclusive to them. Good design can for instance allow a ballistic vehicle to be serviced by simple mobile gantry systems little different to those used at airports now (Delta Clipper, Synerjet) and you can always use a wheeled trolley to move them around as is down with helicopters. As for recovery the advantages of being able to land vertically without need of a runway speak for themselves. The tradeoffs involved in the air traffic control of different design solutions is more complicated and some thought needs to be given to the locations of take-off and landing points in order to make an assessment.
5. A spaceplane will stall and do a nasty belly flop just as surely as any other winged vehicle if power fails soon after take-off. Also just because you can glide it does not mean that you can always reach somewhere suitable. The fact is that no design is inherently perfect but good design can mitigate the risks.

6, 7, 8. None of these requirements says spaceplane and nothing else.

The SKYLON Spaceplane *(continued)*

The above are mostly amplifications with respect to count (1) above but count (2) is a more serious problem for anybody contemplating the issues raised in the article.

SKYLON appears to be based around a similar payload and mission envelope to HOTOL, but HOTOL gained its cost advantage to a very large extent by going for a tightly targeted market segment, communications satellite delivery into LEO. It is not clear that this cost advantage will carry over to the use of spaceplanes of this type in other markets.

Correctly predicting the market during the lifetime of a vehicle is vital to determining a cost-effective design. The authors of the article appear to be putting the cart before the horse by designing a vehicle and then trying to find a market for it. They might get lucky and find that there is indeed a sufficient market for their design but throwing out designs and hoping for the best is a very haphazard way of achieving a market goal such as providing for the Earth launch needs of a space industrialisation programme.

The authors seem to be taking the very common line that to break the vicious circle, high cost = low market = high cost, it is necessary to find a new cheaper launch system. This approach is wrong and is itself contributing to the problem.

Firstly there is a confusion between costs and income. This is largely due to the fact that all previous major programmes were government funded making the distinction pointless. However a truly cost effective system must be run on commercial lines if it is to have a useful long-term future - no government will subsidise the size of programme required for any length of time. Thus income and its relation to costs become of primary importance.

Secondly specific costs are a function of the market acting via investment and design.

These points may seem obvious but their implications appear to have been missed. They imply that there is no technological fix because no one will invest in developing one unless it fulfils some demand; this demand may not be for space transport, for instance a missile built for political reasons may, as a byproduct, be used as a launcher. It is unlikely to be particularly good at its second job and indeed the present disappointing cost effectiveness of the Space Shuttle is a good example of the way in which the market aimed for determines design and hence specific launch costs. In other words:

Market => Investment => Design => Specific Cost

where => means determines.

Another way of putting it is that for a given market size and composition an income can be projected. From this income a development budget can be set, this in turn limits the design options and the extent to which these possible designs can satisfy the market at an acceptable level of profit determines the cost to be offered to the customer.

The upshot is this: to break the vicious circle we need to attack the problem of "low market" not "high cost".

The immediate reaction to this is that market size is determined to a large extent by the price. Wrong, what is determined by price is the extent to which demand is satisfied at a given time. The fact that you cannot satisfy a specific demand because your price is too high does not negate that demand it is still there waiting for a cheaper offer.

The role of the entrepreneur in profitably satisfying a subset of demands using a subset of possible means needs to be emphasized, not any particular means.

In summary I would endorse the articles emphasis on good design but suggest that economics is the main design determinant and that neither economics nor other design drivers limit the options for a cost effective launcher to SSTO airbreathing spaceplanes.

J.G. PEARSALL
Rochdale, UK

SKYLON - Pegasus Link Up?

Sir, The two ***Spaceflight*** (May 1993) articles on SKYLON and HOTOL by A. Bond and M. Hempsell respectively finally gave sceptics a chance to see for themselves that what the "big fuss" was all about - was really a valid technological concept and not just another "pie in the sky" fantasy. What a shame that the EC will not take advantage of its potential, and the "not invented here syndrome" will prevent its acceptance in the US - where the recent demise of the economically abysmal/technologically outrageous NASP project has wiped out any hope of a horizontal take-off SSTO in the near future.

As I see it, the only (long-shot) chance of progress for development of the SKYLON/HOTOL concept lies with private enterprise. Specifically, the consortium that builds and operates the Pegasus launcher might become interested in developing a subscale version of SKYLON. If the SKYLON design could be modified to take maximum advantage of the composite wing and airframe engineering and manufacturing experience acquired with Pegasus, then a minimum of R&D investment could yield a reusable SSTO.

The two craft look superficially similar already, the chief difference being that Pegasus is composed of three separable solid rocket motor stages - a far more complex structure than the single fuselage of SKYLON-type vehicles. Being an expendable launcher, Pegasus of course never has to land. Its B52-launched predecessor, the X-15 rocket plane, solved this problem with a pair of skis and a steerable front wheel. The poor-man's SKYLON could make use of this, as well as other (for example tactical missile ramjet) existing hardware. That would basically leave the novel aspects of the LACE engines and reentry thermal protection as the only major hurdles for the Pegasus people to overcome. If they could get a hundred or more flights out of a single SKYLON-type craft, they would never have to build another Pegasus. The rest of the industry - and the world - would quickly catch-on, and full-size SKYLONS would be plying the skies a few years hence.

It is even conceivable that McDonnell Douglas' Delta Clipper VTOL SSTO could make use of LACE engines, but the latter's low thrust performance during the early air-breathing stage of flight makes them uniquely suited to aerodynamic lift horizontal take-off - exactly the opposite of VTOL, which requires the highest thrust on the launch pad.

JAROSLAV FRANTA
Montreal, Canada

Spaceflight, Received and Read

Sir, The March 1993 issue of ***Spaceflight*** arrived in March - wonderful! I look forward to the ***JBIS*** later. (I am still waiting for the BBC World Wide Magazine so full marks to the BIS for efficiency).

By the way the March 'Into Orbit' issue of ***Spaceflight*** was tops - just like the good old days.

TIM HASSELL FBIS
St Petersburg, Russia

Sir, May I take this opportunity to congratulate you on the content of recent ***Spaceflight*** magazines. I have found the articles on lunar development, re-usable SSTO spacecraft and remote sensing very readable and most informative. Keep up the good work!

W.G. MAXWELL
Banffshire, UK

The Editor welcomes items of correspondence for publication. The right is reserved to shorten material as appropriate.

'Biteback' at the BBC

Sir, Amongst other items dealt with in the BBC's 'self-analysis' programme *Biteback* on 23 May was a complaint from various interested viewers concerning the current lack of any form of recent Science Fiction (excluding *Red Dwarf*) on the BBC. Various BBC officials made general promises concerning future developments, but nothing specific was said.

It is of considerable importance to people interested in maintaining and expanding public interest in space exploration to be able to gain the widest popular forum for their ideas, fiction tending to generate larger, or at least different, audiences than documentaries, however well constructed. I am not sure how much emphasis the BBC puts on ratings at the moment, allowing the last 'Quatermass' serial to be shown by ITV, and closing down 'Dr Who' - which was supposed to be replaced by a series called 'Star Cops', parts of which were quite good, but which seems to have 'died' after one series.

What we need is an attempt by BIS members to make the BBC realise that there is an intelligent, informed audience for good-quality Science Fiction in existence. Whilst composing this letter, I saw another showing of 'Forbidden Planet', still deserving of the description 'one of the most intelligent science fiction films ever made' after some 40 years. I would certainly welcome a drama which had an ending half as upbeat as that of that other recently-shown classic, 'The Shape of Things to Come'.

Having composed this letter, stressing the need for increased public awareness of space exploration and development, I have just found added material for my argument by coming across a letter in *The Times* calling for the abolition of the British National Space Centre, on the grounds that it was not providing value for money.

I have written to the Parliamentary Space Committee, pointing out that the closing of the BNSC would be a false economy. I intend to write to the relevant department at the BBC to see if I can add my weight to those already attempting to broaden the BBC's coverage of space matters.

P.W. DAVEY
Dorset, UK

Mir Amateur Radio Activity

Sir, The cosmonauts that will be active as Radio Amateurs from Mir in 1993-4 and their call signs are as follows:

Call sign	Name of HAM	Crew No.	Date in orbit
U9MIR	Gennady Manakov	13	24.01.93-22.07.93
R2MIR	Aleksandr Poleschuk	13	24.01.93-22.07.93
	Planning List		
R3MIR	Vasily Zibliev	14	01.07.93-24.11.93
R4MIR	Aleksandr Serebrov	14	01.07.93-24.11.93
*	Jean-Pierre Haignere	(Fra)	01.07.93-22.07.93
U9MIR	Viktor Afansiev	15	16.11.93-
R5MIR	Yurij Usachev	15	16.11.93-
R0MIR	(Doctor)	15	16.11.93-
U6MIR	Gennady Strekalov	16	06.05.94
R6MIR or R0MIR		16	06.05.94-
?	Aleksandr Viktorenko	17	30.09.94-
?	?	17	30.09.94-

*still not clear if he will use HAM radio.

From 01.01.93 the cosmonauts were given a new series of call signs. (R - Russia, #-HAM number cosmonaut, MIR - space orbital complex Mir). R0MIR is the call sign for the collective station. The old series U#MIR is still valid. The equipment used onboard Mir will continue to be the same as at the end of 1992.

J.K. ANDERSEN
Skagen, Denmark

Space Station Concerns

Sir, I believe that Johnson-Freese and Handberg expressed many of our feelings and frustrations in their article on the American space station which appeared in ***Spaceflight***, June 1993, p.186.

The space shuttle was a second rate compromise and it looks as if the space station will be a fourth rate compromise if it ever gets built.

In the last two decades, NASA has slipped from being the pride of America, to a pale reflection of its former self.

It has been plagued by an absence of political commitment and suffered from an ongoing lack of direction.

When you combine this with an aerospace industry which likes to do business on the basis of charging $1000 or more for a screwdriver, you are in deep trouble.

The way things now stand, Congress should seriously consider scrapping Freedom altogether and allow NASA to commission the Russians to build a proper von Braun type space station, using Energiya to lift most of the components into LEO.

It would be a useful method of injecting cash into the weak Russian economy and an excellent means of further improving international relations.

Unless the White House and Congress can be made to see the importance of having a large permanently manned orbital science platform and staging post for an eventual return to the Moon the future of American space exploration looks bleak.

BILL ROSE
Norfolk, UK

Pluto Science

Sir, Yet again ***Spaceflight*** is fast with the one-line quotes and technical mini-facts but short on scientific content. I should like to provide some brief background to the mention in the April issue (p.141) of NASA's study of a Pluto mission.

Contrary to John Pike's comments, a mission to Pluto has been in there fighting for scientific merit with all the other missions for the past 5 years. A variety of Pluto mission concepts have been put through the mill of NASA committees and advisory boards and survived. I guess you cannot keep a good idea down.

While there is the obvious motivation to "complete the exploration of the solar system" there are also strong scientific reasons for going to the Pluto/Charon system, two tiny, icy bodies at the edge of the solar system, and soon. Important issues such as the different compositions and densities of Pluto and Charon; the strong variations in reflectivity across Pluto's surface; the tenuous, escaping atmosphere of Pluto with an aerosol and/or inversion layer; etc.; will not be resolved from Earth-based observations and need to be addressed before Pluto recedes from perihelion and its atmosphere condenses onto the surface for 200-odd years.

My personal interest is Pluto's bizarre atmosphere and the possible comet-like interaction of such an out-gassing object with the solar wind at such large distances from the Sun.

Others are more concerned with comparing Pluto/Charon with other icy objects, in search of clues about the origin and evolution of the solar system. At the same time no one is arguing that Pluto science justifies a *Cassini* or even a *Voyager* budget. The *Pluto Fast Flyby* requires taking Goldin's edict to go "Lighter, faster, cheaper" very seriously, and the brightest space scientists and engineers are rising to the challenge. Pluto and Charon may indeed "turn out to be large ice dwarfs" but right now they are hot pieces of real estate.

FRAN BAGENAL
University of Colorado
USA

One Step Beyond ... To Boldly Go...

Sir, The first of the current Radio 4 series 'One Step Beyond .... To Boldly Go ....' was broadcast on April 8 at 19:20 immediately following The Archers and exactly two months to the date of the Horizon programme 'Mars Alive'. As the main object of the One Step Beyond series is to examine the possible impact of specific areas of current scientific research on the near if not the immediate future of our civilisation it was perhaps appropriate that a programme about the possibilities for life on Mars should follow a radio soap about life on the farm.

Although like the 'Mars Alive' Horizon programme the subject of 'To Boldly Go ...' was terraforming, the emphasis and balance of the radio programme was subtly different from the TV presentation. Paradoxically the absence of images seemed to help rather than hinder understanding of some of the more technical aspects of the subject. The contributors included many of the most notable US scientists who have been, and are, engaged in the study of how we might make Mars suitable for life, some of whom like Professor Robert Haynes and Jim Oberg were not featured in the Horizon programme. The case for a more gentle 'green' bio-geophysical approach to terraforming was once again well presented by Chris McKay of NASA Ames Laboratory and that advocating a more rapid controlled application of energy and a synergistic technology by BIS Fellow Martyn Fogg. Work on engineering solutions to create a near-planetary-wide biosphere was presented by another BIS member Richard Taylor.

The latter part of the programme examined some of the ethical aspects that might arise if any trace of indigenous life was to be discovered on Mars. All in all the programme was a great success, it not only examined the subject of terraforming at a serious but approachable scientific level but it brought out the enthusiasm, conviction and humour with which the scientists involved tackle their work. As a science, terraforming has been served particularly well by these BBC TV and Radio programmes in this BIS Jubilee year and it is particularly rewarding for us to realise the important part the Society and some of its members have played in making these programmes possible.

RICHARD L.S. TAYLOR
London, UK

Terraforming

Sir, "Mars Alive" . . . television programmes and weekend study schools . . . the terraforming movement seems to be gathering momentum.

Before we go too far, please let us stop and ask one important question: "Is it right for us to modify another planet for our own use?"

Even from a strictly scientific viewpoint, there are doubts. For example, it will take years of study to understand how Mars evolved to its present condition. As soon as the terraformers start work, valuable evidence is lost for good. You cannot set aside an area of "virgin Mars" for scientific study if you are modifying the whole planet!

And there are deeper philosophical questions here, about the moral rights and wrongs. Over the centuries here on Earth, plans devised "for the good of humanity" have driven to extinction plant and animal species by the thousand; almost the whole land surface of the planet has been changed; the oceans and the entire atmosphere bear the apparently ineradicable traces of humanity's misguided ambitions.

Must we repeat our mistakes on another planet? Having spoilt our own, are we just going to walk away from it, and go and spoil another?

How much better it would be to turn some of this energy and enthusiasm to "terraforming the Earth", and making it once again a planet that is truly fit to live on!

Dr FIONA VINCENT
Mills Observatory
Dundee, UK

Interplanetary Communications

Sir, Space communications are often thought of naturally as consisting of the relation of a transmitter to a receiver. This is a natural dual model of communication based on the psychological paradigm of human speech. This is not, however, the best way to beat noise, nor does this model encapsulate the natural pre-requisite for intelligent communication, which is a shared knowledge-base between receiver and transmitter, in other words, 'Memory'. For example, given a compendious book of messages associated with times, a single strong pulse at the appropriate time of day, for which energy has been saved up, will beat noise and convey a message in difficult conditions. In a small way, error correcting codes use memory also.

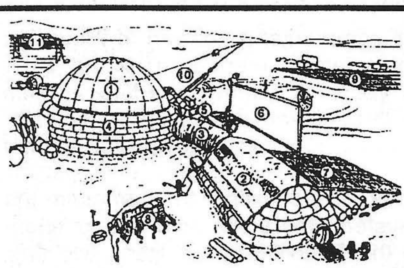
A paper by the writer [1] shows how all logic can be done by the relation 'precisely two out of three true'; relating this to planetary and interplanetary communications we can have a ternary model of two transmitters and one receiver. One advantage of this is that one very large and powerful transmitter can be devoted to accurate clock transmissions to provide a common reference for phase-coherent detection, which has been shown on Earth to have the best range/power ratio of all. Trans-Atlantic Morse messages have been received from a transmitter using a torch battery.

The logic can be used to structure the arrangement of transmitters and receivers in such a way that the same signal transmitter can at small power send more than one message at once; the message received depending on the timecode reference used. In this way signals can be sent through the emptiness of space to the planets in a very flexible way, the splitting-up of message content being done at the receiver by a time, not a frequency, relation.

M.C. SOPER, MA
Oxon, UK

References

1. M.C. Soper, "A simplest Logic of all", *ELEKTOR*, Vol. 17, No. 195, December 1991.
2. N. Weiner, *Cybernetics*, McGraw Hill, 1948.



'Lunar Base' Competition Winners

Lucky readers to whom prizes will shortly be despatched are:

First Prize (a set of 5 videos of the Gemini Program) to:

L. Raoul, Belgium

Consolation Prizes (the video 'STS-49 Mission Highlights') to:

S. Darrill, UK
O.B. Moakofi, Botswana
A. Salmon, UK
J. Sweeney, Eire

The answers were (A) 9; (B) 6; (C) 4; (D) 1; (E) 2 and (1) the launch (or landing) site (2) oxygen.

Overseas readers were clearly as enthusiastic as UK readers for joining in the competition. Other countries, apart from those among the winners, from which entries were received are: Australia, France, Greece, Germany, Holland, Italy, Slovakia, Sweden and USA.

Andy Salmon ***finds one more song that now has a 'Space' connection . . .***

Oh My Darling Clementine

A space probe will be launched in 1994 to map the Moon and to flyby a near-Earth asteroid. It is from a rather unusual source: The Strategic Defense Initiative Organisation*, working with NASA.

The genesis of the mission was when the SDI organisation asked the Naval Research Laboratory to build a spacecraft in order to test light-weight sensors and components.

BY ANDY SALMON
West Midlands, UK

A 'Deep Space' Mission

The mission was costed at about $35-40 million for operations in low Earth orbit. Then it was realised that targets would need to be created for the sensors to look at that would add another $10 million.

A different approach was therefore taken. The craft was to be sent on a "deep space" mission beyond low Earth orbit. Its targets would be the Moon and the near Earth asteroid Geographos. The "hard" radiation environment outside Earth's protective magnetic field would be a good test of the sensors' radiation resistance.

A small expendable launch vehicle, such as the Pegasus, was considered initially - since the craft was budgeted at about 135 kg weight. To minimise any risk to the schedule a refurbished US Air Force ICBM was eventually chosen - which also meant that the craft could be heavier (it is currently 217 kg "dry" weight).

NASA was invited to participate and, with proposals for Lunar orbiters being squashed by Congress every time they were mentioned, its scientists leaped at the chance to fly on an *approved* mission. Although Clementine is optimised for technology trials rather than science, it will still be a significant mission.

Launch and Flight Path

Launch will be in late January 1994, atop a Titan 2G rocket from Vandenberg Air Force Base on the Californian coast-line.

A Thiokol 37 FM solid propellant motor will fire after about a day in Earth orbit. Clementine will be on a "slow-boat" route to the Moon after Trans Lunar injection - via two highly eccentric "phasing" orbits with apogees near the Moon's orbit. This route allows a seven day launch window from Earth and a low impulse requirement for Lunar Orbit Insertion when the Moon is reached.

One month after launch, Clementine enters Lunar polar orbit (400 km perilune, 8,300 km apolune). 227 kg of hydrazine and nitrogen tetroxide propellants are carried for three-axis stabilisation and for orbit changes.

For two months Clementine will map the entire Moon in 12 spectral bands - using UV/visible and near-IR imagers together as an imaging spectrometer to study surface composition.

The lidar may be used as a laser altimeter over the 30 deg N to 30 deg S portion of the Moon but it is at the limit of its ranging distance. The lidar *will* produce multicolour pictures - with a resolution of 6-10 m/pixel.

The mid-IR imager will produce pictures of selected lunar areas with a resolution up to 20 m/pixel.

The first month sees perilune near 30 deg S latitude then an engine burn moves perilune to 30 deg N.

Onboard power comes from two solar arrays and data is sent back to NASA's Deep Space Network by a High Gain Antenna at one end of the craft. There is 1.6 gigabyte of data storage capability onboard.

Clementine now sets off on the second part of its mission. It first enters another eccentric "phasing" orbit around the Earth before a lunar flyby gives it a gravity "sling-shot" assist for Geographos encounter orbit insertion on May 27, 1994.

Ninety-six days later, on August 31, 1994, Clementine will flypast the stony asteroid 1620 Geographos at less than 1900 km distance. It will be 8.5 million km from Earth at the time. Twelve-channel imaging spectroscopy and high resolution imaging (as good as 1 m/pixel) will be carried out. Nominal end of mission is after Geographos data transmission.

Looking Ahead

Clementine will provide information about the Moon and an asteroid such as their surface morphology, topography and composition.

Total experiment cost is $70-80 million (including launch vehicle and operations).

Clementine-1 will use 1990 level technology. A follow-on mission, Clementine-2, with even lighter sensors and systems is being planned. It has been booked for a 1995 launch on a Taurus rocket built by Orbital Sciences Corporation. The launch site will be Cape Canaveral.

Although being a military-managed mission (harking back to the days of Explorer 1), Clementine seems to be the way forward in these days of "faster, cheaper, better".

* Now the Ballistic Missile Defense Organisation.

References

1. *Aviation Week & Space Technology*, November 23, 1992.
2. Paul D. Spudis, "To the Moon and Geographos", *LPI Lunar & Planetary Information Bulletin*, February 1993.

Innovative Technology

The sensors, to be built by the Lawrence Livermore National Laboratory, consist of a UV/visible CCD imaging system; a near infra-red CCD imaging system; a mid-infra-red imaging system; and a lidar imaging system and laser altimeter.

Onboard systems are miracles of light-weight technology; the UV/visible camera weighs 440 g; the pair of star trackers carried for orientation weigh 334 g each; and the Inertial Measurement Unit (part of the navigation system) weighs just 600 g. For comparison the 1970s technology IMU of a US Air Force Transport (the C-141) weighs about 30 kg. Clementine has been touted as carrying the most advanced hardware to fly in space to date.

Launch Report

Taiwan to Launch Satellites

Taiwan plans to have its first satellite launched in 1995 as part of a US$520 million space programme and is negotiating with the Swedish Space Corporation to buy a small, experimental 'micro-satellite' for at least $1.5 million.

The satellite will be placed in orbit by a foreign launcher, probably an Ariane. The micro-satellite will serve as a 'pathfinder' for Taiwan's own research and communications satellites programme in which three satellites will be placed in orbit by 2005. The first of these, due to be launched by the end of 1997, will be experimental and the government has decided that the second and third will be communications satellites. The government has begun seeking foreign companies to help develop the satellites and they will be launched by foreign agencies.

South Korea Set for Launch No. 2

The second science satellite built by Korean scientists is scheduled for launch on September 1. The satellite will be lifted off from the Kourou Base in French Guiana by an Ariane rocket and will orbit at an altitude of 820 km.

Weighing just 50 kg and measuring 35.2 x 35.6 x 67 cm, the satellite, named Uribyol-2 (Our Star-2), is equipped with KASCOM (a 32 bit computer), two high performance cameras to photograph the Earth and other high-tech communications and electronic gear.

Korea's first satellite Uribyol-1 was jointly designed by KAIST (Korea Advanced Institute of Science and Technology) and Surrey University and was built by Surrey University at a total cost, provided by the Korean Government, of nearly 7 billion won. The second satellite Uribyol-2 is being built in Korea which has invested about 3.1 billion won in its research and development.

Korea intends to launch "Mugunghwa" a communications satellite equipped with 5,300 telephone circuits and three television relay channels in June 1995.

Pump Spring Delays STS-57

Launch date for STS-57 was moved from June 3 to June 20 following the discovery of an improperly marked spring in an engine pump.

The STS-57 mission is highlighted by the retrieval of the European observation satellite Eureca and the first flight of the commercial spacelab facility 'Spacehab'.

The suspect spring was found in the oxygen turbopump for main engine No. 2, the inspection stamp on it being in a high-stress area and causing concern that the spring could break at liftoff whereupon the engine would shut down.

Forthcoming STS Launches

Mission	Launch Target Date	Orbiter Vehicle
STS-51	July 17	Discovery
STS-58	Early September	Columbia
STS-60	November 10	Discovery
STS-61	December 2	Endeavour

SATELLITE DIGEST-254

Satellite Digest is our regular listing of world space launches. It is based upon a more detailed monthly satellite listing published by the Molniya Space Consultancy prepared by Phillip S. Clark.

Spacecraft	Int'l Desig.	Launch	Launch Site	Launch Vehicle	Mass kg	Orbital Epoch	Inclin. deg	Period min	Perigee km	Apogee km	Notes
Cosmos 2239	1993-020A	Apr 1.79	Plesetsk	Cosmos-B	825 ?	Apr 2.14	82.93	104.75	967	999	[1]
Cosmos 2240	1993-021A	Apr 2.60	Plesetsk	Soyuz	6,500 ?	Apr 2.72	62.85	89.62	190	322	[2]
Cosmos 2241	1993-022A	Apr 6.75	Plesetsk	Molniya	1,900 ?	Apr 9.30	62.88	718.95	641	39,772	[3]
Discovery	1993-023A	Apr 8.23	KSC	Shuttle	93,682	Apr 11.31	57.01	90.46	293	302	[4]
SPARTAN 201	1993-023B				1,289	Apr 11.49	57.01	90.43	292	299	[5]
Cosmos 2242	1993-024A	Apr 16.33	Plesetsk	Tsyklon-3	2,000 ?	Apr 19.98	82.53	97.74	634	668	[6]
Molniya-3 44	1993-025A	Apr 21.02	Plesetsk	Molniya	1,750 ?	Apr 22.09	62.83	735.63	614	40,618	[7]
ALEXIS	1993-026A	Apr 25.58	EAFB	Pegasus	109	Apr 26	70.00?	100.4 ?	740 ?	835 ?	[8]
Columbia	1993-027A	Apr 26.62	KSC	Shuttle	103,191	Apr 27.06	28.46	90.53	297	304	[9]
Cosmos 2243	1993-028A	Apr 27.44	Tyuratam	Soyuz	6,300 ?	Apr 28.61	70.35	88.77	192	236	[10]
Cosmos 2224	1993-029A	Apr 28.15	Tyuratam	Tsyklon-2	3,000 ?	Apr 28.53	65.03	92.78	404	418	[11]

NOTES

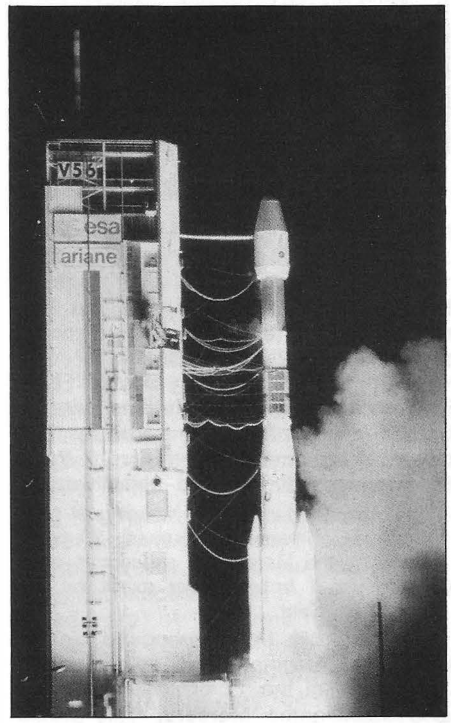
1. Military Tsikada-class navigation satellite, co-planar with Cosmos 2173.
2. Fourth generation, close look photoreconnaissance satellite.
3. Early warning satellite, replacing Cosmos 1974.
4. STS-56 mission carried six astronauts: K D Cameron (commander), S S Oswald (pilot), M Foale (mission specialist 1, MS-1), K D Cockrell (MS-2) and E Ochoa (MS-3). Shuttle undertook the ATLAS 2 (Atmospheric Laboratory for Science and Applications) mission. Mass quoted above is that for landing. Launch time was 05.29 GMT and landing at Kennedy Space Center was Apr 17.48 (11.38 GMT).
5. SPARTAN (Shuttle Point Autonomous Research Tool for Astronomy) 201 is the first successful flight of the SPARTAN 200 series craft, and is a free-flying satellite undertaking solar studies. Deployment from Discovery was 1993 Apr 11.22 (05.11 GMT) and capture was 1993 Apr 13.31 (07.20 GMT).
6. Believed to be a Worldwide ELINT satellite. The orbital plane is located midway between those of Cosmos 2221 and Cosmos 2228, the previous two launches in this series: such an alignment is unusual since the standard separation is 60°.
7. Communications satellite, co-planar with Molniya-3 41. Actual launch time was 00.23 GMT.
8. ALEXIS (Array of Low Energy X-ray Imaging Sensors) planned to perform a year-long (minimum) X-ray all-sky survey. Following launch no telemetry was received from the satellite: it is probable that the solar panel which carried the main communications antenna was torn off during the Pegasus third stage firing. NASA B-52 aircraft took off from Edwards Air force Base and flew 130 km off the coast of Monterey. Pegasus was separated at 13.56 GMT at an altitude of 13.3 km. Orbital data for ALEXIS have not been released by USSPACECOM: the data given above are based upon the Orbital Sciences Corporation News Release on April 25, which gave an approximate 70°,

India Delays PSLV Launch

The Indian government has announced the delay of the launch of its powerful Polar Satellite Launch Vehicle (PSLV), which was scheduled for launch this spring after the successful test of all four of its propulsion stages. A government statement in Parliament said the PSLV would be launched "in the second half of 1993" without explaining the delay.

The PSLV is designed to place one-ton remote-sensing satellites into orbit and is a successor to the Augmented Satellite Launch Vehicle, successfully launched last May after several abortive efforts.

The PSLV is one of two powerful rockets that India is developing on its own. The other is the Geostationary Launch Vehicle (GSLV), whose planned development by 1996 will give India an undisputed intercontinental ballistic missile (ICBM) capability. In May 1992 the US introduced limited trade sanctions against ISRO and Russia's Glavkosmos to discourage the two civilian space agencies from going ahead with the transfer of cryogenic engine technology for the GSLV, which can be diverted to India's large ballistic-missile programme. India contends that the US action is unfair because it needs the 12-ton cryogenic engines to build powerful rocket boosters to place the next generation of Indian weather and communications satellites in orbit.



V56: Lift-off of the launcher Ariane 42L from Kourou, French Guiana at 00:56:32 GMT on 12 May 1993. This was the first launch of the version equipped with two liquid strap-on boosters.
Arianespace

EUTELSAT Launches

The first five EUTELSAT I satellites were launched for ESA by Ariane during 1983-1988 and later transferred to the Eutelsat Organisation. More recently, a series of five EUTELSAT II satellites have been or will be launched between 1990 and 1994. An Ariane 4 has been selected for launching the the tenth satellite, EUTELSAT II F5, into geostationary transfer orbit at the end of 1993 or early 1994.

Galaxy IV Delay

On June 4, Arianespace decided to delay the launch of V57, which was then scheduled for June 9. Concern arose when an anomaly was detected in electronic components of the same type as those used in the onboard computer and interface unit that are aboard the Ariane 42P launcher. The payload is the Galaxy IV communications satellite to be placed in geostationary orbit at longitude 99°W.

400-450 nautical miles orbit.

9. STS-55 mission carried seven astronauts: S R Nagel (commander), T T Henricks (pilot), J L Ross (mission specialist, MS-1), C J Precourt (MS-2), B A Harris (MS-3), U Walter (payload specialist, PS- 1) and H W Schlegel (PS-2). Shuttle orbiter carried German-sponsored Spacelab-D 2 (mass 11,351 kg) in its payload bay. Mass quoted above is that projected for landing. Launched at 14.50 GMT: planned landing at Kennedy Space Center prevented by bad weather: landed Edwards Air Force Base (confirmation of landing time awaited as this listing is being prepared).
10. Apparently a rare flight of the third generation photoreconnaissance satellite. No manoeuvres had taken place through to early May 3. Actual launch time was 10.35 GMT.
11. Second launch of an ELINT Ocean Reconnaissance Satellite (EORSAT) within the space of a month. Orbit is co-planar with Cosmos 2238 (1993-018A), but 120° behind the older satellite.

ADDITIONS AND UPDATES

1977-061A Cosmos 925 decayed from orbit Apr 29.

1986-017GX Mak 2 decayed from orbit Apr 1.

1990-007A Hiten, the first Japanese lunar probe, impacted the Moon's surface near the crater Furnelius (38 °S, 5 °E) Apr 11.27 (06.30 GMT).

1991-005A Cosmos 2122 decayed approximately Mar 28.4 (09.00 GMT).

1993-006A Cosmos 2232 was a replacement for Cosmos 2001.

1993-012A Launch time was 18.32 GMT. After the initial undocking from the Mir Complex on March 26, Progress-M 16 (1993-012A) re-docked later the same day after retreating 70 metres from the station. Final undocking came on Mar 27.18 (04.21 GMT), followed by deorbit the same day.

1993-013A Add the operating orbit for Raduga 29: Apr 12.17, 1.46°, 1,436.26 minutes, 35,772 km, 35,808 km. The satellite is located over 12 °E. Launch time was 02.28 GMT.

1993-014A Russian literature indicates that the Start-1 launch vehicle comprises the three-stage SS-25 missile plus a fourth stage.

1993-015A Correct launch time for UHF 1 is Mar 25.90 (21.38 GMT). Add new orbital data: Apr 4.39, 26.92°, 621.96 minutes, 219 km, 35,298 km. The satellite has been abandoned in its incorrect orbit.

1993-016A Launch time was 02.21 GMT.

1993-017A Add new orbital data for Navstar 19: Apr 3.25, 54.87°, 723.70 minutes, 20,194 km, 20,453 km.

1993-018 Launch time was 12.00 GMT. The Russian launch announcement named the launch vehicle as "Tsyklon-M", although the Tsyklon user manual calls the variant "Tsyklon-2".

1993-019A Progress-M 17 docked with the Mir Complex Apr 2.22 (05.16 GMT). Add post-docking orbit: Apr 3.81, 51.62°, 92.44 minutes, 393 km, 395 km.

Astronomical Notebook

Mercury Polar Flyby

Mention has recently been made in *Spaceflight* (April 1993 p.139 and June 1993 p. 212) of the polar regions of Mercury. Their close observation has now become a possibility with a recent proposal submitted to NASA.

The proposed Mercury Polar Flyby spacecraft is one of 11 missions selected by NASA for further study under the Discovery programme. The Mercury Polar Flyby spacecraft has two objectives:

(1) to complete the surface imaging of Mercury which was started nearly 20 years ago by the Mariner 10 spacecraft, and
(2) discover if frozen water exists on the planet's polar caps.

The mission is being proposed by the Lunar and Planetary Institute, Houston.

Another of the 11 proposed missions also investigates Mercury. This would orbit the planet and remote sense its surface, atmosphere and magnetosphere. It is a proposal of JPL, Pasadena, California.

For further information on NASA's Discovery programme see ***Spaceflight***, May 1993, p.151 and June 1993, p.208.

ALEXIS Telemetry

ALEXIS (Array of Low-Energy X-Ray Imaging Sensors) is a small astrophysics mission whose purpose was to generate an all-sky map of the astronomical soft X-ray background and to look for coronal sources and transients. Following its launch on April 25, no telemetry was received from the satellite. (See *Satellite Digest* on p.246).

Satellites Observe Supernova

NASA's International Ultraviolet Explorer (IUE) satellite has obtained new evidence that red supergiants end their existence in massive explosions from observations of a new supernova on March 30.

This Type II supernova took place about 12 million light-years from Earth in the galaxy (M81) in the Ursa Major constellation. It has been designated SN1993J because it was the tenth supernova discovered this year.

The supernova's nearness and the quickness with which the IUE was able to observe it were critical factors that enabled scientists to verify this aspect of stellar evolution theory. A supergiant star is massive with a diameter similar to the Solar System out to the planet Jupiter. Stellar evolution theory has long maintained that red supergiants can explode to become supernovae but, in the only previous case where the type of star that produced a supernova explosion has been definitely determined, it turned out to be a smaller and hotter blue supergiant. That supernova occurred in 1987, 160,000 light-years away and was also observed by IUE.

The difference between red and blue supergiants is that the blue variety are believed to have evolved from red supergiants after shedding much of their extended atmosphere. Blue supergiants are thus smaller than red supergiants. IUE's observations of the supernova revealed that the exploding star is surrounded by a thick shell of slowly expanding gas. Heated to very high temperatures by the enormous energy released in the stellar explosion, the ultraviolet emissions from this glowing gas were detected by IUE.

A red supergiant loses large amounts of material through a slowly moving wind flowing outward from the star. The presence of this glowing gas in the first observations of the supernova means that it must be close to the explosion and that the star must have been in a red supergiant phase shortly before its demise.

In a Type II supernova explosion, the central core of the supergiant star collapses after the star uses up its nuclear fuel. This central implosion sets off an explosion of the outer layers of the star, leaving behind a small, incredibly dense neutron star or possibly a black hole.

Goddard's Dr Yoji Kondo, IUE Project Scientist said "The light it produces for a few weeks is roughly equivalent to the brightness of the whole Milky Way galaxy, which contains a few hundred billion stars". Explosions of these huge stars are not uncommon but they are rarely observed so close, so this one, on a cosmic scale, is practically a next door neighbour.

Supernova X-Rays Detected

Asuka, a satellite launched last year to detect X-rays from various stars and galaxies, has also recorded the emission from Supernova SN1993J. The X-rays were at least a million times stronger than those emitted by the Sun and showed that gas temperatures around the supernova reached more than 100 million degrees Celsius.

Diamonds in the Sky

Findings by scientists at NASA Ames Research Center, Mountain View, California have challenged the theories of how galaxies evolve. They have observed huge amounts of microscopic diamonds in star-forming clouds in the Milky Way galaxy, which contrasts with the observation of hydrocarbons.

Observations of these two very different types of interstellar hydrocarbon dust suggest that the materials are not mixing, as generally assumed up to now. It had been thought that materials flowed freely between the dense clouds and coalesced into stars, planets and comets.

"We thought the dust and chemicals in spiral galaxies mixed freely over relatively short astronomical periods", said Lou Allamandola, head of the science observation team. "We are looking at star-forming clouds expecting to find simpler forms of hydrocarbons, molecules that make up materials similar to candle wax or gasoline. These molecules more easily form in the conditions of space but, instead of finding the expected simpler hydrocarbon molecules, we found large quantities - the equivalent of planetary masses - of micro-diamonds dominating every star-forming cloud. The surprise is that, in the dense clouds, the waxy, saturated hydrocarbons are not there. Because of the slowly spinning spiral arms of the galaxy, we assumed they would be mixing", Allamandola said.

Billions of tons of micro diamonds were discovered last year in dense star-forming clouds. As doctors use dye to track fluids in a human body, astronomers have used micro diamonds and other solid interstellar materials to track the movement and evolution of matter in space.

The current theory is that star-forming clouds form by gravitational forces in space. As their masses increase, so do the gravitational forces. Eventually stars ignite in the densest regions in galaxies. The pressure from the light in new stars pushes outward, breaking up the remains of the clouds and pushing leftover material from the clouds out into space.

The Allamandola team puzzled unsuccessfully for more than a year before identifying abundant microscopic diamonds in star-forming clouds. Having observed a prevalence of softer hydrocarbons surviving in the harsher regions between the clouds, they expected these or similar materials to be common in the dense clouds as well. "In retrospect, our discovery of microscopic diamonds should not have come as a surprise, because they previously have been found in several types of primitive meteorites", Allamandola said.

The team's findings also eliminated specific sources for the diamond flecks found in meteorites. The observations from Hawaii's Mauna Kea infrared telescope found micro diamonds to be widespread and very abundant, comprising 10 to 20 percent or all interstellar carbon. This suggests that uncommon star types or relatively rare supernova are not uniquely responsible for their formation and support the theory that meteoric diamonds form in many regions of space, either in carbon star atmospheres or as the result of carbon grains colliding at high speeds in interstellar space.

An Astronomical Task !!

Guide Star Catalog

The Guide Star Catalog (GSC) Group at the Space Telescope Science Institute has compiled a digital map of the entire sky, 60 times larger than any existing catalogue and containing almost 19 million celestial objects, including 15 million stars between 9th and 15th magnitude.

The catalogue was constructed by scanning and converting into digital form a total of 1,477 sky survey plates taken with the Oschin Schmidt Telescope on Palomar Mountain (operated by the California Institute of Technology) and the UK Schmidt Telescope at Siding Spring, Australia (operated by the Anglo-Australian Observatory).

In constructing the catalogue, the GSC Group faced unique challenges in large database construction, maintenance and access software. It required much experimentation, innovation, and reliance upon emerging computer data storage technologies.

The catalogue construction process began in 1985 following four years of prototyping, design and development, and required another four years to complete. Ultimately, GSC programmers wrote some 200,000 lines of computer code to help construct the catalogue. Plate scanning and data processing alone required two 8-hour shifts, seven day per week and grew to three shifts for about one year.

The GSC Group utilised optical disk technology to solve the archival and distribution problems associated with this enormous sky inventory. The raw Schmidt-plate scans fill 400 optical disks, with each disk containing nearly 1.6 billion bytes of data apiece. For distribution to astronomical institutions, the entire GSC was placed on to a set of two CD-ROM disks. Each disk stores nearly 600 million characters or the equivalent of a printout on 8½-by-11-inch paper measuring 30 miles long and weighing one ton.

To access the raw plate scans easily, the GSC Group developed a user-friendly software package called the Guide Star Astrometric Support Package (GASP). Mainly used for planning observations, GASP quickly provides HST users with precise information about their target fields and can display many types of digital images made with almost any telescope.

HST utilises Fine Guidance Sensors to locate and lock on to a pair of guide stars near the edge of the telescope's field of view. The GSC was constructed to ensure that guide stars are available wherever the HST looks and serve as a database which supports the automated scheduling of observations and telescope operation without direct or "realtime" control from the ground.

Besides its support of HST operations, the GSC is a major reference for ground-based astronomy applications, such as tracking comets and asteroids, providing precise finder charts and obtaining large numbers of stellar spectra using fibre-optics.

SPACE PROBE DIARY

Hiten

11 April

The Hiten probe launched on January 24 1990 by the Japanese Institute of Space and Aeronautical Science, crashed on the lunar surface on 10 April. The 4 ft 7 in diameter, 2 ft 9 in long probe was used to provide information on gravity assist to change an orbit instead of relying on rocket engine bursts.

The satellite moved from Earth orbit to one around the Moon on 15 February 1992, using lunar gravity and only a small amount of propellant.

Magellan

18 May

NASA's Magellan spacecraft will dip into the atmosphere of Venus, as from May 25, in a first-of-its-kind "aerobraking" manoeuvre, lowering the spacecraft's orbit to start a new experiment. This technique will use the drag created by Venus' atmosphere to slow the spacecraft and circularise the spacecraft's orbit. Currently, Magellan is looping around Venus in a highly elliptical orbit.

The aerobraking technique has never been used before on a NASA planetary mission. The new orbit should enhance the scientific return from what is already one of NASA's most successful space missions.

In the absence of enough thruster fuel, aerobraking is the only way to effect such a large change in Magellan's orbit.

Better measurements of Venus's gravity field, particularly at latitudes near the planet's poles, have now become possible.

Magellan has been collecting data on Venus' gravity for the past 8 months though measurements from its current elliptical orbit are blurred at high latitudes by the height of the spacecraft above the surface - about 1,300 miles (2,100 km) near the north pole and 1,700 miles (2,800 km) near the south pole.

Magellan will complete its fourth 243-day orbital cycle at Venus on May 25. During each of the 8-month cycles, Magellan orbits from north to south while the planet turns once underneath the spacecraft. Data has already been obtained on the elevation, slope, radar reflectivity and radar emissivity over 98 percent of the planet. In the upcoming manoeuvre, flight controllers hope to lower the spacecraft from a low point of 100 miles (170 km) and high point of 5,300 miles (8,500 km). The target orbit is 125 by 375 miles (200 by 600 km) which would alter orbit time from 3¼ hours to 90 minutes.

Mars Observer

3 May

The Mars Observer spacecraft was returned to normal cruise mode on April 30 after spending 38 hours in a fault protection mode known as "contingency mode". In this mode, the spacecraft automatically switches from the high-gain to the low-gain antenna and repositions itself in a more favourable orientation towards the Sun.

No hardware problems were involved and the spacecraft performed the switching perfectly. JPL's flight engineering team will continue to study the problem until an adequate software fix can be designed and uplinked.

18 May

Mars Observer returned to normal cruise mode on Monday, May 17, eight days after it had automatically switched to a self-protective mode on Sunday, May 9. While recovery from contingency mode had been possible last week, the flight team took the opportunity to analyse memory readouts of the incident more thoroughly and develop a software fix to improve the spacecraft's attitude reference performance.

The software fix involved a relatively minor parameter change to celestial body sensing software. Using the upgraded flight software, the spacecraft can now identify its orientation in space more accurately and prevent the switch-over to contingency mode that has been occurring lately.

The contingency mode causes the spacecraft to point at the Sun automatically. In that orientation, the solar array faces the Sun directly and is subject to solar wind. Had a much longer period of time elapsed e.g. four to five times as long, the spacecraft's trajectory could have been affected. However, the spacecraft is still on course for arrival at Mars on August 24, 1993 and the fourth trajectory correction manoeuvre, planned as a backup to correct any errors in the final trajectory, is not likely to be needed.

All spacecraft subsystems are operating well. The science payload will be powered on now that the spacecraft has been restored to normal cruise mode. Two-way communication has been reestablished using the high-gain antenna. The spacecraft is now about 11 million miles (19 million km) from Mars and 144 million miles (232 million km) from Earth, travelling at a velocity of about 4,300 miles (7,200 km) per hour with respect to Mars.

The Starship as an Exercise in

Part 2 - A World

In Part 1 of this article* we argued that a federal world government is a prerequisite to solar system colonisation, and thus to interstellar travel, as it would offer the surest way of satisfying the political conditions that must be met before human society will be ready for such an undertaking. Here we conclude these arguments by considering why a world government would wish to support a world space programme.

Why a World Space Programme

There are at least four compelling arguments for an ambitious space programme within the context of a federal world government:

Support for High-Technology Industries

A world government would inherit a large number of high-technology aerospace companies, whose business is at present dominated by the production of weapons. These companies directly employ over a million people in the US alone [1], and many millions more depend on them indirectly. A world government with little demand for military products may find it politically necessary to offer these companies alternative business. An ambitious space programme is the obvious alternative because the technologies involved are similar and many of the companies hardest hit by disarmament already have a significant interest in the development of space hardware [2,3]. For example, the world's four largest arms producing companies in 1989 were, in order of decreasing arms sales [4], McDonnell Douglas, General Dynamics, Lockheed, and British Aerospace; all four are predominantly aerospace companies, and all four would find a switch from arms to space relatively painless. In 1989 Lockheed and McDonnell Douglas were, after Rockwell International (itself arms producer number 10), the second and third leading NASA contractors [5].

Even if a world government found it politically and economically possible to let these industries wind down, there are other reasons why this would be highly undesirable. The fact is that these companies represent an enormous pool of high-technology expertise, relevant to many other areas of the world economy, which would be at least as important to a future world government as it is to national governments today.

The Cosmic Perspective and Global Solidarity

A federal world government is desirable primarily as an institutional framework within which many of our most pressing problems can be satisfactorily addressed. However, in spite of the obvious urgency of this task, considerable nationalistic opposition can be expected and, even if federation is successfully achieved, the danger of disintegration will be present for some time. Anderson [6] referred to nations as essentially 'imagined' political communities, "*imagined* because the members of even the smallest nation will never know most of their fellow members ... yet in the minds of each lives the image of their communion". This point was taken up by Hobsbaum [7], who pointed out that, throughout history, states have had "every reason to reinforce ... the sentiments and symbols of 'imagined community' wherever and however they originated". Thus we see that a world government will want to encourage new, *global*, visions of humanity to supplant politically divisive, nationalistic ones.

One way of achieving this will be through global cooperative projects with which widely separated people can identify. A world government could initiate many worthwhile developmental projects which would fulfil this role to some extent. However, from the point of view of enhancing global solidarity, it is important that some of these cooperative projects possess sufficient intrinsic excitement to catch the imagination of the majority of human beings everywhere. The exploration of space is an obvious candidate for such a programme. It has a unique advantage through its ability to add a *cosmic* dimension to the world view of ordinary men and women. The image of Earth's place in the cosmos provides powerful testimony to the unity of humanity, and thus carries a potent, if implicit, argument for the political unification of human societies. At present, only a tiny fraction of human beings appear to have incorporated this perspective into their personal philosophies, but a high-profile global space programme could stimulate many others to do so, thereby playing a significant role in building a sense of global community.

A Moral Equivalent of War?

In 1910 the philosopher and psychologist William James published his famous discussion on the need for human societies to find a 'moral equivalent of war' [8]. Although a pacifist, James was concerned that pacifism *per se* was unable to provide substitutes for the ideals of heroism, glory, adventure etc., which (arguably) provide powerful psychological attractions to war for many people. James realised that the problem does not lie solely, or even mainly, in the minds of fighting men, but also in the collective psyche of public opinion. He therefore argued that it is desirable to find an alternative to war that would satisfy many of the psychological needs for which militarism appears to cater, but which would avoid its obvious disadvantages. This view was reiterated by Russell [9; p.65] when he wrote that

> *"If the world is ever to have peace, it must find ways of combining peace with the possibility of adventures that are not destructive".*

The exploration and colonisation of outer space, starting with the Moon but moving inexorably through the solar system towards the stars, would constitute a grand, *non-destructive*, human adventure, which may largely satisfy these criteria. By providing the world with a plausible 'moral equivalent of war', a substantial space programme could be of considerable social value to a world government. Even if a point is eventually reached when war becomes unthinkable, a world government may nevertheless find it desirable to provide an increasingly well-off human population with a sense of purpose and adventure. As space is to all intents and purposes infinite, its exploration and development may provide a safety valve for human energies into the indefinite future. At the very least, it would enable us to avoid the stagnation at the 'end of history' which Fukuyama [10,11] has recently argued to be the ultimate fate of a peaceful democratic world.

Extraterrestrial Resources

The major economic tasks facing a world government will involve the reorganisation of the world economy along the lines of sustainable development, and the promotion of acceptable standards of living in Earth's poorer regions. These tasks will require significant investment of global resources, and will limit the extent to which less urgent projects are considered justifiable. Nevertheless,there are persuasive economic reasons why a world government may wish to main-

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World Government
Space Programme

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tain a steady investment in space infrastructure, even while tackling these other problems. These arguments are centred on the possible future requirements of the world economy for extraterrestrial resources.

The realisation that the Earth's natural resources are finite has been growing for several decades and now overshadows most speculations on the future of human civilisation. Indeed, Meadows *et al* [12; p.126] went so far as to state that "...under the assumption of no major change in the present [world economic] system, population and industrial growth will certainly stop within the next century, at the latest". This is an extreme conclusion, and the simplistic economic model upon which it was based has been much criticised. However, insofar as the Earth is a finite system, the conclusion (although not the timescale) is probably sound. Genuine 'limits to growth' will one day confront human civilisation unless there is a major change in the global economic system. As the management of the world economy will be one of the primary functions of any future world government, this problem may be expected to have a high priority in its thinking.

While there is much that can be done to postpone the onset of a resource-starvation crisis beyond the timeframe envisaged by Meadows *et al* (e.g. greatly increased energy efficiency, development of renewable energy sources, large scale recycling, and development of an 'industrial ecology', [13]), these measures will not, by themselves, eliminate the ultimate threat of economic stagnation and decline. Thus, in addition to encouraging the implementation of these shorter term policies, a responsible world government would be forced to identify longer term solutions. As pointed out by Martin [14] and Schultz [15], there is only one obvious way out of this dilemma, namely the utilisation of extraterrestrial resources. As the resources of the solar system are, to all intents and purposes, infinitely greater than those of Earth alone, the industrialisation of the solar system has the potential to solve the 'limits to growth' problem by opening a previously closed planetary economy to unlimited supplies of external raw materials.

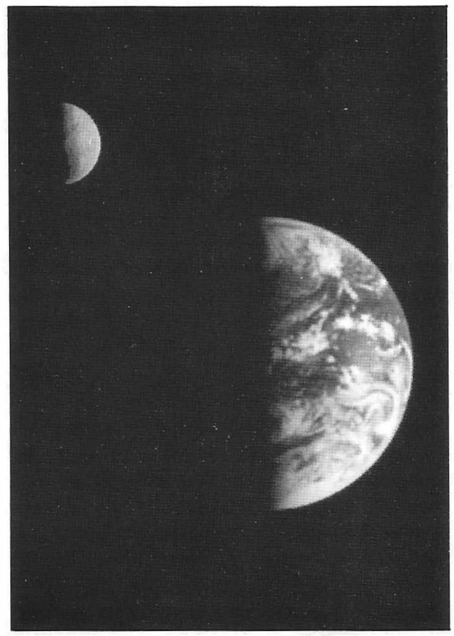
It is probable that, given proper management [13,16], the world economy will be able to operate successfully without recourse to extraterrestrial resources for several centuries. However, if a transition to extraterrestrial resources is to occur smoothly, significant infrastructural investment will be needed well in advance. A responsible world government would thus view the development of a space infrastructure as a worthwhile, and perhaps essential, investment in the future of the world economy.

Financing a World Space Programme

We argued in Part 1 that the only logical means of financing a programme of space infrastructural development would be to transfer resources from what is now the military sector of the world economy, and that only a world government could accomplish this.

The world's present military expenditure of $\$10^{12}$ pa amounts to approximately 6% of its GDP. Given that a world government will find it politically and morally imperative to spend much of this 'peace dividend' on other projects, but may regard a space programme to be worth some fraction of it, 1% of world GDP may be a realistic figure for the latter. This is one sixth of present-day military spending, or about $180 billion per year at today's prices. It is over twelve times NASA's 1991 budget of $14 billion, or somewhat over half the US military budget of $300 billion [4]. In the longer term, this value of 1% of GDP will increase as a result of economic growth.

Although 1% is a very small fraction of global GDP, it would constitute a much larger proportion of a federal world government's total expenditure. Typically, Western governments today have total incomes amounting to 30 or 40% of GDP [17]. However, a federal world government would be much less centralised than existing national governments and would be unlikely to have a comparable fraction of the world's GDP at its disposal. Assuming that it were able to take over the global military budget (presently about 6% of world GDP), and raise additional revenue through moderate fiscal measures (e.g. environmentally targeted taxes on raw material and energy consumption), an income of 10% of the global GDP may not be unreasonable. The proposed world space budget may then account for about 10% of world government expenditure (the remainder being devoted primarily to development projects on Earth itself). This is comparable to the fraction of governmental expenditure typically controlled by a major ministry within existing national governments, and suggests that space policy could become (relatively) as important to a future world



Will a World Space Programme require a World Government?

The Moon in orbit about the Earth taken from the Galileo spacecraft on December 16, 1992.
JPL/NASA

government as, say, foreign policy is to present-day national governments. This comparison is quite appropriate as space policy (pursued for economic and other reasons) is the only *external* policy that could concern a world government.

Although a detailed analysis of how fast infrastructural developments could proceed given this level of investment is not considered here, it is possible to get an intuitive grasp of what may potentially be achievable by comparing the costs of past and future space projects with the suggested world space budget of $180 billion. At today's prices, the space shuttle development cost was in the region of 20 to 35 billion dollars [18,19]; the cost of space station Freedom is also projected to be about $30 billion [20]; and the cost of the Space Exploration Initiative (which, in its more ambitious versions [21], would involve a expanded space station, the creation of a lunar outpost and the landing of people on Mars in the early decades of the next century) is estimated to be about $500 billion [22]. These correspond to average annual expenditures of about $3 billion per year for the shuttle and Freedom (assuming ten year programmes) and perhaps $25 billion per year for the SEI (assuming a twenty-year programme).

Thus, a world space budget corre-

sponding to 1% of world GDP would be more than five times that required to develop the space shuttle, the space station, and the SEI simultaneously. Maintained consistently over many decades, this level of funding would be more than sufficient to establish the basic elements of space infrastructure discussed In the Introduction of Part 1.

Conclusion

In this article (Parts 1 and 2) we have identified a number of political preconditions to the large-scale development of the solar system and have argued that a federal world government will be required if these conditions are to be fully met. As the development of a significant industrial infrastructure in space will be essential before any attempt can be made at rapid interstellar travel, the creation of a world government is also a prerequisite to this longer term objective. I am well aware that many will consider all this to be hopelessly utopian, and I therefore reiterate that we have here been concerned with Identifying political preconditions. I have not claimed that these preconditions will necessarily be met, only that without them many of our most ambitious hopes for the future of humanity in space may never be realised.

In order to illustrate the importance of these political developments, consider the repercussions of the federal constitution drawn up at Philadelphia in 1787 for the thirteen (previously independent) North American states. That constitution also was not inevitable (and many Americans, jealous for the sovereignties of their separate states, were in fact opposed to it [23]), but we can now see that its adoption was a political precondition to all that the United States has subsequently accomplished. By placing the resources of an entire continent at the disposal of a single government, the federal principle eventually enabled the United States to undertake projects utterly beyond the reach of small, European-style, nation-states. Quite literally, the federal constitution worked out at Philadelphia in 1787 was (among much else) a prerequisite to the landing of man on the Moon almost two centuries later.

The creation of a federal world government would extend this process to its logical conclusion. By raising the largest unit of political organisation from the continental to the planetary scale, it would create the conditions of geopolitical stability, disarmament, and economic growth required for (among other things) the financing of an ambitious world space programme. It is difficult to see how the inhabitants of a politically and economically fragmented planet could ever be in a comparably strong position from which to aim at the stars.

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SOCIETY MEETINGS DIARY

14 August 1993

48th Annual General Meeting

The 48th Annual General Meeting of the Society will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, on Saturday, August 14, 1993 at 12 noon. Details of the Agenda will be published in due course.

Admission is by ticket, available to Corporate Members (i.e. Fellows of the Society) only, who should apply in good time enclosing a stamped addressed envelope.

22 September 1993 10 am - 4.30 pm

European Rocketry in the 1930's

As part of the Society's Anniversary Year the History Working Group is holding a Symposium on European Rocketry in the 30's. Contributions have been invited from Germany, France, Russia and the UK. The 30's is seen as a particularly interesting decade in that much theoretical and practical work was undertaken that laid solid foundations for later projects.

Whilst much publicity has surrounded the experimental and theoretical work carried out in Germany an enormous amount was also carried out elsewhere, particularly in Russia. Much of this story has yet to be told.
Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Advance Registration is necessary.
Registration: Forms are available from the Executive Secretary. Please enclose a sae.

15 - 17 October 1993

SPACE '93: Space Initiatives

This Special Society two-day meeting commemorates the Society's Diamond Jubilee, 1933 - 1993. See opposite page for details.

16 - 22 October 1993

44th International Astronautical Congress

The 44th International Astronautical Congress will be held in Graz, Austria, from October 16 - 22, 1993. Details of the Programme, Registration Forms, etc. are available from BIS HQ.

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.
It may occasionally happen that, for reasons outside its control, the Society has to change the date or topic of a meeting. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always recheck the scheduled meetings in the latest issue.

1 September 1993 7 pm - 8.30 pm

SOHO - A Unique ESA/NASA Mission to Survey the Sun

D.M. Simpson, Matra Marconi

6 October 1993 7 pm - 8.30 pm

Microsatellites on Micro-budgets

Prof. M. N. Sweeting

The prohibitively high cost of space projects has effectively restricted first-hand access to space to a handful of nations and international agencies. Spacecraft have grown ever larger and more complex and are also taking longer time-scales from concept to orbital operation. Advances in VLSI micro-electronics have catalysed a new species of small, low-cost yet sophisticated and highly capable 'microsatellites' - complementing, and sometimes providing an alternative to, high-cost traditional satellites.

The lecture describes the University of Surrey UoSAT microsatellite programme which reviews the key technologies, management techniques and potential applications of small satellites.

LIBRARY

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. The Library will also be open on Saturdays between 10.00 am and 1.30 pm on the following dates:

- 21 August
- 18 September
- 23 October
- 20 November
- 18 December

Membership cards must be produced.

Journal of the British Interplanetary Society

The following complete volumes of ***Journal of the British Interplanetary Society (JBIS)*** are available from the Society in limited numbers.

Year	Vol	Issues per Vol	Price £	Year	Vol	Issues per Vol	Price £
1946/7	6*	7	24	1970	23	12	30
1948	7*	6	24	1971	24	12	30
1949	8*	6	24	1972	25	12	30
1950	9*	6	24	1973	26	12	30
1951	10*	6	24	1974	27	12	30
1952	11*	6	24	1975	28	11	28
1953	12*	6	24	1976	29	11	28
1954	13*	6	24	1978	31	12	30
1955	14*	6	24	1979	32	12	30
1956	15*	6	24	1980	33	12	30
1957/8	16*	10	24	1986	39	12	30
1959/60	17*	12	24	1987	40	12	30
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JBIS

The July 1993 Issue of the Journal of the British Interplanetary Society is now available and contains the following papers:

Pioneering Rocketry and Spaceflight (Part III)

NASA and the Public Understanding of Space Science • Liquid Rocket Propulsion Applied to Manned Aircraft - in Historical Perspective • NASA Cryogenic Fluid Management: Space Experiment Efforts 1960-1990 • The Preservation of Space-Related Historic Sites • A Note on the History of the Westcott Establishment, 1946-1977

Copies of JBIS, priced at £15.00 (US$30.00) to non-members, £5.00 (US$10.00) to members, post included, can be obtained from the address below. Back issues are also available.

The British Interplanetary Society
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Spaceflight

The International Magazine of Space and Astronautics

Polar Platform for 1998 Earth Watch

UK Main Space Focus ● Modular Design
Twelve-Country European Project

Space Shuttle Competition

Space Videos to be Won!!

- HITEN MISSION ENDS
- SPACE AT THE PARIS AIR SHOW
- SHUTTLE MISSION REPORT: STS-49
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The BIS Video Collection

The BIS is proud to offer a stunning record of man's exploration of space brought to your home on video.
All videos are extracted from original footage.

Apollo 8: Go For TLI

This Saturn V flight was man's first journey around the Moon and forerunner of the Apollo lunar-landing flights. The three-man crew (Borman, Lovell and Anders) set course for the Moon, passed behind it and transferred to a lunar orbit, circling the Moon ten times in 20 hours. Their many still photographs and much cine film helped to decide on landing sites for later missions. The final TV transmission took place while 97,000 miles from Earth. *22 mins*

Apollo 9: Three to Make Ready

Building on the successful flight of Apollo 8, a lunar module was tested in space, as was the life support system of the space suit. Two of the three-man crew (McDivitt, Scott and Schweickart), transferred to the Lunar Module, moved 100 miles away from the Command Module and then returned to rendezvous with it. The two men then transferred back to the Command Module and the Lunar Module was jettisoned. *17 mins*

Apollo 10: To Sort out the Unknowns

Lift-off to a trans-lunar orbit by Stafford, Young and Cernon, with views of Earth and system checks *en route*. There was loss of communications signal while passing behind the Moon as the craft transferred to lunar orbit. Signal acquisition returned when the spacecraft reappeared, with TV pictures showing the Lunar Excursion Module (LEM) undocked from the Command Module and descending to within 50,000 feet of the lunar surface. Direct communications between Control and LEM failed so access was made *via* the CM. LEM subsequently rendezvoused with the CM, the crew transferred again and LEM was jettisoned. *26 mins*

STS-49 Mission Highlights

The details of this flight by the Shuttle Endeavour, 7-16 May, 1992, are well covered, e.g. the preliminaries of suiting-up, the White Room, entry to orbiter, removal of gantry, count-down, engines start, lift-off, and detailed operations during the flight. A principal aim was to retrieve the Intelsat VI satellite which had previously failed to reach synchronous orbit. Though more difficult than expected, it was achieved and sent on its way. A second aim was to practice basic space station assembly work by Extra-Vehicular Activity (EVA). This was also very successful. The video concludes with an interesting press interview with the crew. *1hr 50 mins*

Mission of Apollo Soyuz

In July 1975 spacecraft from the Soviet Union and the United States blasted off on an historic mission. Two days after blasting off Apollo and Soyuz docked high above the Atlantic Ocean. This NASA film covers the scientific and technological achievements of the mission and stresses the spirit of cooperation and friendship. *28.5 mins*

Time of Apollo

In 1961, President John F. Kennedy set forth the task... "This nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth". This film is a tribute to the historical accomplishments of the Apollo programme. *29 mins*

Skylab: The First 40 Days

Records the launch of the unmanned Skylab 1, the major problems that followed and the repair during the manned Skylab 2 mission. Includes on-board sequences of daily work routines and some of the experiments. *22.5 mins*

Skylab: The Second Manned Mission

Covers the Skylab launch activities and docking with the orbital workshop. Includes observations of student experiments, crew medical experiments, exercise routines and the activation of the Earth Resources Experiments Package. *36.5 mins*

The World Was There

This NASA film, using original footage from the sixties, shows how the news media of the World covered the manned space launches of NASA's project Mercury. *27.5 mins*

STS-49 Post-Flight Crew Press Conference

Shuttle flight STS-49 proved to be the most dramatic mission in the 11-year history of the programme. Endeavour, on its maiden flight, had to chase the Intelsat-6 satellite three times. The first two attempts to capture the satellite ended in failure. On the third and, finally successful attempt, it took a record-braking three spacewalkers to grab the slowly spinning satellite. In this NASA production the STS-49 crew describe their daring mission. *22 mins*

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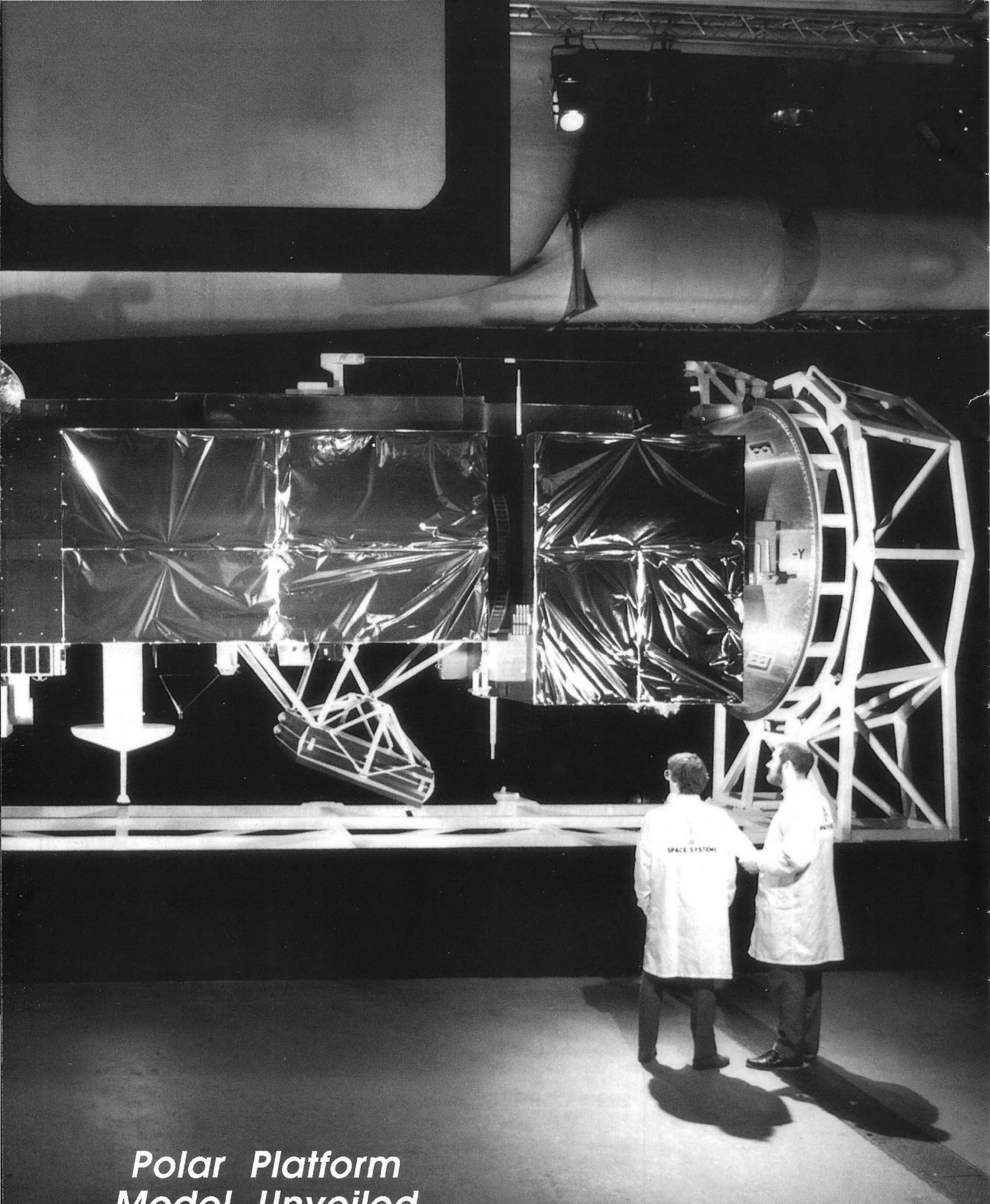
Spaceflight

The International Magazine of Space and Astronautics

Published By The British Interplanetary Society

Vol. 35 No. 8 **AUGUST 1993**

Front Cover: ENVISAT-1, The first ESA Polar Platform to be launched in mid-1998 as a successor to ESA's European Remote Sensing Satellites, ERS-1 and ERS-2. The picture highlights two key instruments on ENNVISAT-1: The Advanced Synthetic Aperture Radar, ASAR and The Michelson Interferometer for Passive Atmospheric Sounding, MIPAS. *ESA*



Polar Platform Model Unveiled

TAKING A CLOSE LOOK at the full size model of the Polar Platform which was constructed by Polymeric Composites of Bristol. For its public presentation the platform was configured for the ENVISAT-1 mission. The model can be reconfigured into any combination of modules reflecting the flexibility of the real Polar Platform. It measures approximately 10 meters by 3 meters by 2 meters and weighs nearly two tonnes. Its purpose is to enable engineers to try out the Polar Platform's ground facilities, to test interfaces, and to determine the best cable and piping runs. The model is designed so that it can be used in the cleanrooms used to construct and test the actual spacecraft. *BAe*

Polar Platform for 1998 Earth Watch

The major commitment of the UK space programme is to Earth Observation. The UK is taking a leading role in ESA's future Earth Observation programme in which launches of ENVISAT-1 and -2 are planned for 1998 and 2003 and of METOP-1 and -2 for 2000 and 2005.

* * *

In this issue, the spotlight is put on a central part of UK involvement - the Polar Platform itself and also the Advanced Synthetic Aperture Radar (ASAR) to be used on ENVISAT spacecraft:

Polar Platform Model Unveiled

On 22 March British Aerospace (Space Systems) Ltd at Bristol hosted the public unveiling of a full scale mock up of the Polar Platform spacecraft. Many of the British companies involved in the Polar Platform project together with the European Space Agency, and the (then) British Space Minister Edward Leigh MP, used the opportunity to explain the satellite and its objectives to the press.

Recalling the European Space Minister's meeting in Granada in November 1992, Edward Leigh said, "I am delighted I was able to encourage my fellow ministers ... to treat Earth Observation as a priority." This resulted in a commitment to an extensive Earth Observation programme based around the Polar Platform spacecraft. "Polar Platform is not just a new satellite, it will be the basis of a series of sophisticated missions to provide a very wide range of environmental data."

MARK HEMPSELL
University of Bristol

The minister outlined the main principles behind UK space policy. "It is several years since Britain put Earth Observation at the head of its list of space objectives. This I believe was the right decision because viewing Earth from space can do so much. Not only does it enable monitoring of global warming, ozone depletion and weather patterns, but it provides unique data about resources and human activity generally. The developing world, for example, has benefited considerably from space derived information about crop cycles, the availability of water, and other resources."

In the longer term this policy should be widened. "Having decided to put space to work we would be foolish not to do so in every possible way. Britain's civil space programme ... has rightly concentrated in recent years on Earth Observation, but we have also been very successful in satellite communications and space science. It was important for me therefore at Granada that we also reminded Europe of the potential and value of the HOTOL technologies within the FESTIP investigative programme."

Mr Philip Goldsmith Director of ESA's Earth Observation programmes explained the Polar Platform's role in the overall ESA programme.

The first European polar orbiting Earth observation spacecraft, ERS-1, was launched on 17 July 1991. It has proved outstandingly successful and will soon be followed by ERS-2 which is essentially a repeat of ERS-1 with some improvements in the experimental payload.

The first Polar Platform called ENVISAT-1 will continue and expand upon the work started by ERS-1. It will be launched in 1998 and carry 10 instruments dedicated to monitoring the global environment.

After ENVISAT-1 ESA is planning for the next polar platform to be launched in 2000. This is called METOP-1 and its instruments concentrate on the analysis of the world's weather systems. Later platform launches are envisaged as the platforms come to the end of their five year life, ENVISAT-2 in 2003 and METOP-2 in 2005.

Mr Goldsmith pointed out that all the Polar Platforms will need to make use of another ESA spacecraft the Data Relay Satellite to get the vast quantities of data they produce to the ground.

He concluded. "We should be proud of what we are achieving in Europe in observing our Earth's system for the mutual benefit of all mankind, but I am particularly pleased that the UK is showing such leadership in this particular area."

The ENVISAT-1 programme will cost Europe around £1.5 billion. The majority of the UK space budget is being used to support this programme and so British companies are leading many of the key areas as well as the project as a whole. Currently some 210 people are employed in the UK on the programme of which 150 are on the spacecraft prime team at British Aerospace.

British industrial interest was shown in talks by Rod Jenkins who is the Polar Platform Project Manager at British Aerospace, and Mr Richard Wignall Deputy Managing Director of Matra Marconi Space. Mr Wignall highlighted the Advance Synthetic Aperture Radar (ASAR) which will be manufactured by Matra Marconi Space while Mr Jenkins explained the design features of the other ENVISAT experiments and the Polar Platform bus.

The Polar Platform is the main focus of the UK space programme so its success is of great importance. Unlike other major ESA programmes started in the 1980's it has progressed well and is now moving into the detailed design and engineering model testing stage. There was a certain degree of justifiable pride amongst the UK engineers that they were doing a good job on an important satellite. 1998 should see the fruits of their work in orbit helping to manage the Earth's complex industrial civilisation.

Key British Organisations Involved in the Polar Platform Programme

British Aerospace Space Systems Ltd. at Bristol: *Polar Platform Prime Contractor.*

Com Dev Europe at Aylesbury: *Front end electronics for Advance Scatterometer (ASCAT) experiment.*

Logica at London: *Leads an 18 company team designing the ground segment. The subcontractors include Vega, Cray, and EOS from the UK.*

Matra Marconi Space at Portsmouth: *Prime Contractor for Advanced Synthetic Aperture Radar (ASAR).*

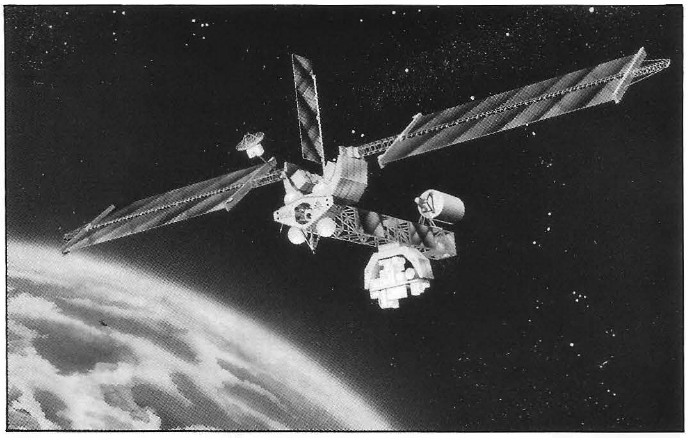
Rutherford Appleton Laboratory at Didcot: *Leads the development of the Advanced Along Track Scanning Radiometer (AATSR).*

Early History of the

The concept of a "Space Platform" as a European programme contributing to the establishing of an in orbit infrastructure was due Dr. Bob Parkinson of British Aerospace Space Systems (BAe) at Stevenage. He generated the idea while he was working with other European companies on ESA sponsored studies into the best way to participate in an international space station programme led by the United States.

A platform seemed an attractive system which would usefully complement the US space station, while being relatively immune to any changes on the American side during the development programme.

MARK HEMPSELL
University of Bristol



1984 Space Platform.

In April 1984 at a BIS symposium Bob Parkinson and myself presented a paper [1] which outlined the Space Platform concept in a public arena for the first time. In the audience was Mr Antony Roberts of the DTI who was struck with the platform concept and discussions began on whether this could become a UK led contribution to the international space station.

A "platform" in the context of the space infrastructure is an orbiting system that provides a common resource base for a number of payloads. The aim being to separate the development, establishment and maintenance of the services such as power, attitude control, data handling and such like from the production of the payload. This was expected to have three major benefits:

1. **Cost**: Although larger and more complex than a typical satellite the sharing of the services over several payloads means the cost of providing these services per payload is much lower.

2. **Reliability:** The platform and the many payloads on it make servicing by manned flights a practical proposition increasing the long term reliability and enabling smaller payloads to benefit from in orbit servicing although no single payload could justify it alone.

3. **Accessibility:** Because payloads can be added at any point in the platform's life they do not have to be designed along side, and launched with, the platform. This means the timescale and complexity of a scientific or applications project would be reduced. Instead of each project being a separate spacecraft development, on the platform only the development of the payload's specific instruments would be required. It was hoped that the lead time for space projects using the platform could be reduced to a year or two before flight rather than the seven years or more that is currently typical.

The 1984 Platform concept (see figure) was based around four major pieces of hardware:

- the BAe Spacelab Pallet for carrying both payloads and service equipment
- an MBB deployable truss boom as the main structure
- a Fokker solar array concept called Sola
- a BAe propulsion stage for orbit maintenance and reaction control

This early platform concept was essentially an unmanned space station. The basic platform was to be launched by the Space Shuttle and involved a considerable amount of on orbit assembly. A half sized Spacelab Pallet of experimental payloads would be included on the first construction flight. Subsequent Shuttle flights would not only service the platform, but add further experimental payloads. These would be mounted on Full or Half Pallets which would attach to the Platform's truss boom structure by a standardised berthing port.

In the early days the Space Platform was primarily seen as a facility that would co-orbit with the manned space station. It would be used for payloads that were not suitable for the main station for disturbance, contamination or other reasons. It was envisaged that after this first co-orbiting platform, other platforms of the same basic design would be launched into polar orbit and possibly even, geostationary, lunar and planetary orbits. Building more platforms in different orbits was seen as a means of extending the cost and operational benefits of an in orbit infrastructure to these new locations.

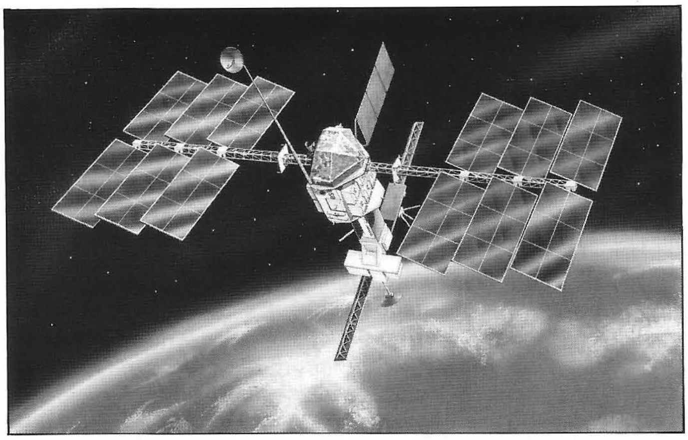
Over the remainder of 1984 during the debate over participation in the space station programme the platform concept was accepted in the UK. At a meeting in January 1985 between the then space minister (Geoffery Pattie) and British industry representatives it was endorsed as a sensible option for Britain to concentrate its efforts on. In Europe it was also accepted as a useful addition to the other elements of the Columbus programme. Columbus being the umbrella name given to all the European contributions to the American Freedom space station programme.

However during the 1984/1985 debate the mission emphasis had altered. By 1985 it was primarily seen as a polar orbiting platform and was called "Polar Platform" by ESA. However it was still called "Space Platform" by British Aerospace as other orbits were still under consideration. In a paper delivered in May that year Peter Conchie (the responsible BAe director) and Bob Parkinson outlined the UK conclusion that "there was a need for a Polar Platform first, but not necessarily only a Polar Platform"

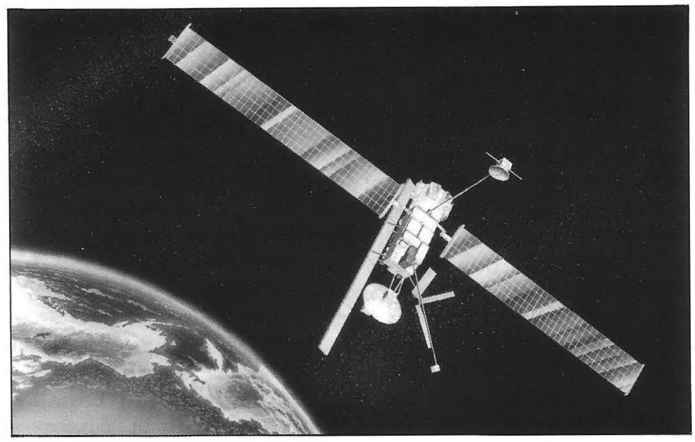
There were a number of factors driving the increased emphasis on polar orbit. The German led Man Tended Free Flyer (MTFF) would be able to provide much of the capability thought to be required of a platform that co-orbited with the Freedom Space Station. So there was little justification for a second European co-orbiting system. Another consideration within the UK was that the majority of potential new users of space were seen to be in the Earth Observation field and a polar platform suited their needs best. This was the start of the current UK emphasis on space based Earth Observation as the principle objective of UK space policy.

USA studies had reached a similar series of conclusions regarding platforms and a larger USA polar platform was also part of the Freedom programme. This would complement the

Polar Platform: 1984-87



1985 Space Platform.



1986 Space Platform.

European Platform as one would overfly the Earth in the morning, while the other would overfly in the afternoon.

The Platform design had also altered in line with the new emphasis. The 1985 Platform (see figure) was still launched on the Space Shuttle but was smaller and could be launched with an almost complete payload complement. This was a gravity gradient stabilised design some 18 meters long in its initial configuration. However like the original concept it was expandable by extending the central structure composed of tubular spacers and connection nodes.

In February 1985 ESA issued three Requests For Proposals (RFPs) for phase B of the Columbus programme. These were the MTFF resource module (eventually won by Dornier), the pressurised manned modules (eventually won by Aeritalia) and the Polar Platform. There was also an overall system coordination workpackage awarded to MBB/ERNO. All through 1985 the British Aerospace space infrastructure team at Stevenage, together with subcontractors across Europe, were preparing the proposal for the Platform and negotiating with ESA. By Easter 1986 the uncontested Phase B contract was awarded to the British Aerospace team.

By this time the interest in placing platforms in non-polar orbits had diminished still further. So the "Space Platform" became the "Polar Platform" even within British Aerospace. However it was now not a "Platform" in the infrastructure sense of the word but simply a large scientific satellite with the payloads developed as part of the overall programme and all launched with the spacecraft. As a result of this change in the spacecraft philosophy British Aerospace moved the Polar Platform work from the infrastructure team at Stevenage to the scientific satellite team at Bristol once the Phase B contract had been won.

By the start of Phase B the Platform had moved from a Space Shuttle launch to an Ariane 5 launch. Partly as a result of the commitment Europe was making to the new launch system and partly as it became increasingly unlikely that the Shuttle would ever fly into polar orbit. This 1986 version (see figure) would have a full payload complement at launch and would not be expandable. It was approximately 9 meters long and weighed about 10 tonnes of which about 2.5 tonnes would be payload.

At this point the only vestige of its manned infrastructure origins left in the design was the ability for astronauts to maintain the Platform in orbit. In this respect the design followed similar practices to the Hubble Space Telescope and the Solar Maximum Satellite which are both designed for on orbit servicing and repair by Shuttle astronauts. At that time the USA was building a Shuttle launch pad at Vandenberg which would have allowed manned flights into polar orbits. However the review of Shuttle activities after the loss of Challenger, and the increasing concern about the radiation environment in polar orbit meant that by 1987 work on the Vandenberg pad was abandoned and it was clear the Shuttle would never be able to fly to polar orbit.

This left the European Hermes/Ariane 5 system as the only possible manned system that could reach the Platform. However its planned payload (around 3 tonnes) was totally inadequate for a servicing mission. Further it was looking increasing unlikely Hermes would be able to reach any kind of orbit with this payload let alone the demanding high polar orbit where the Polar Platform would be located. So in 1987 the decision was made to remove the expensive and heavy requirement for in orbit servicing. This move brought the platform to its current operational philosophy and now only the somewhat inappropriate "Platform" tag indicates the project's infrastructure origins.

Looking back it seems the original Space Platform was soundly based. The Shuttle with its manipulator arm and extensive crew habitation and EVA facilities is a potentially splendid system for servicing man tended platforms which satellites like EUREKA and LDEF have only slightly exploited. With hindsight the main problem with the initial concept, once it was located in polar orbit, was the reliance on the Shuttle being available for construction and servicing missions. While this seemed a reasonable assumption at the time (considering the launch pad at Vandenberg was under construction) it highlights the dangers of basing proposals on a supporting infrastructure that has not yet reached operational status.

The Polar Platform history shows a programme which has kept its focus on its real objectives, a lesson other in-orbit infrastructure programmes would have done well to note. Clearly the original large man tended platform would have been more spectacular, but it would also have been inappropriate, indeed unworkable, for the Earth Observation customers it is designed to serve. However the current Polar Platform design has benefited from its infrastructure heritage. Its modularity and flexibility directly descends from its history and enable it to handle almost any conceivable Earth observation mission for the next two decades.

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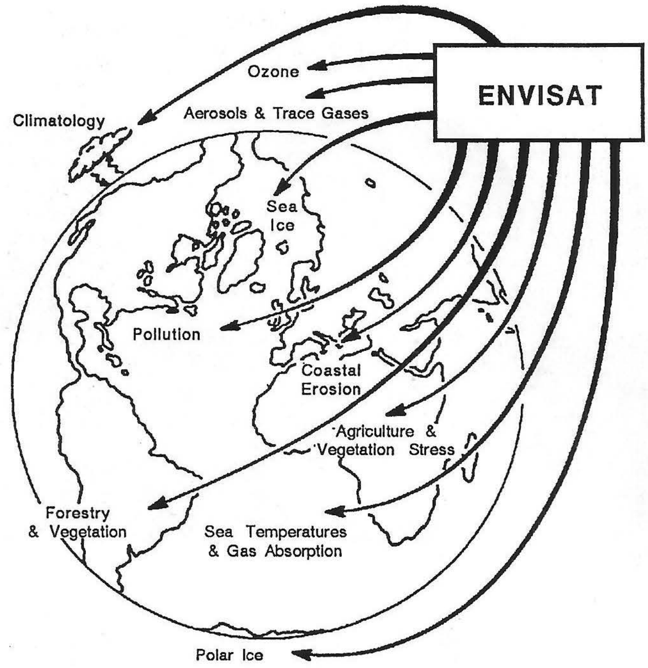
The Polar Platform

What It is and What It Provides

Our environment is continually undergoing evolutionary developments caused by natural activities and changes. Today, however, this sensitive balance is more and more affected by human activities with such well known issues as the 'greenhouse effect', acid rain, oceanic pollution and the threat to the Earth's ozone layer. Such is the threat to mankind of these effects that the environment has become an issue of international concern. As part of the international monitoring effort the European Space Agency (ESA) is developing the Polar Platform, a satellite capable of meeting all the requirements of future Earth Observation missions. The project is being led by British Aerospace Space Systems Limited and involves more than 35 companies from 12 countries. Through Polar Platform and the sensors that it carries more can be learnt about the environment and the effect both natural events and human activities have on its stability and our future.



ENVISAT-1: Examples of instrument applications.

SIMON CHALKLEY
and
JUDITH SIMPSON
British Aerospace Space Systems Limited
Earth Observation & Science Division,
Bristol

Polar Platform

Polar Platform is seen to be the workhorse for future Earth Observation missions in polar orbits. This is achieved through its size and resources, which allow many instruments to be flown together, and its modularity which allows it to be assembled into different sized versions to meet the exact requirements of any particular mission.

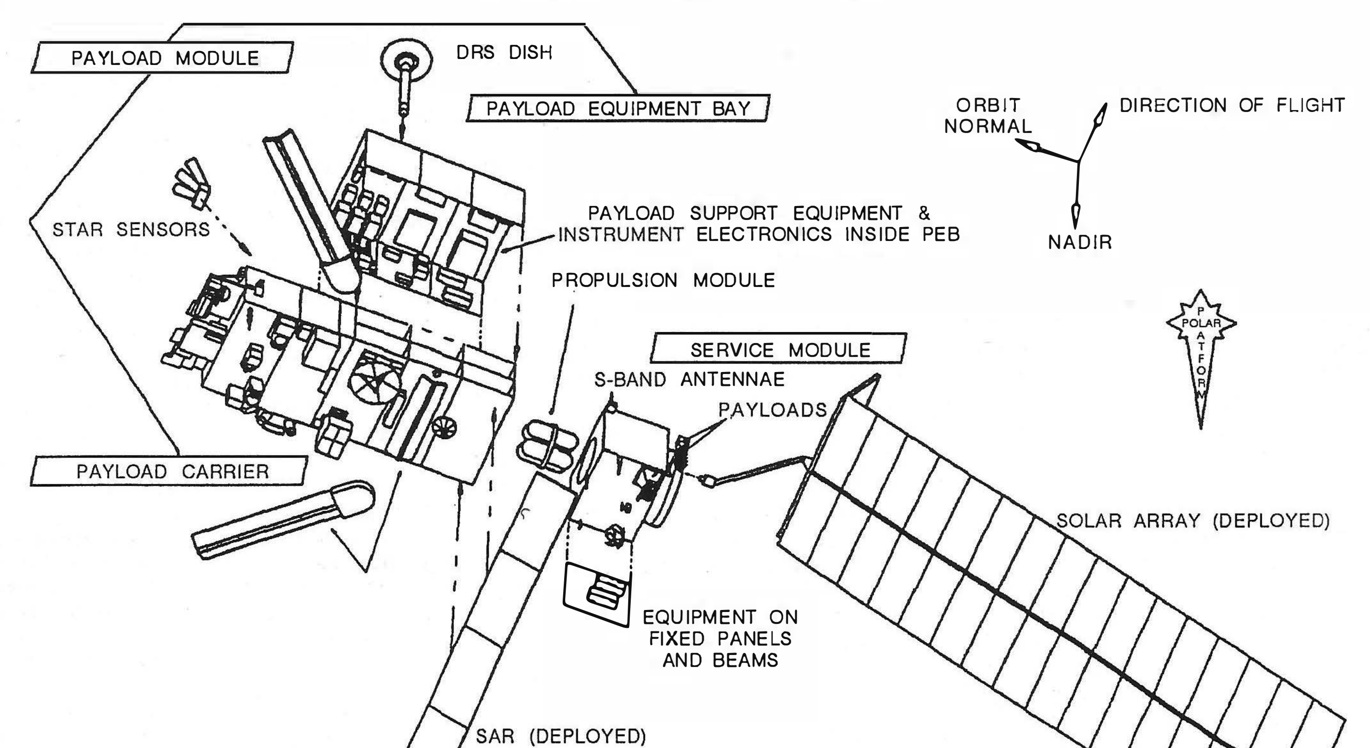
The Polar Platform is essentially a spacecraft bus on which a set of payload instruments is installed. The instruments perform scientific or application mission observations whereas the PPF provides the support services and functions which are needed for the instrument operations.

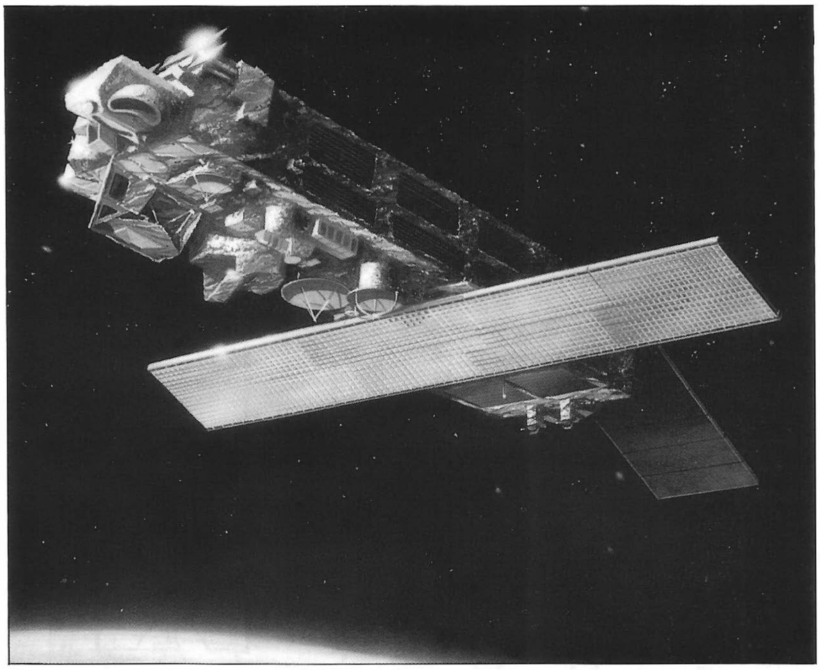
The PPF comprises two modules, the Service Module (SM) and the Payload Module (PLM). This functional split allows parallel development and manufacture of the SM and PLM, both of which have highly modular designs.

The Service Module

The SM is based largely on an extension and re-use of the Spot 4 design and provides the essential services that are required on every mission. These include power generation and distribution, attitude and orbit control, propulsion, telemetry and telecommand allowing communication be-

Polar Platform Modular Concept





Artist's impression of the 10m antenna of Matra Marconi Space's Advanced Synthetic Aperture Radar (ASAR) on ESA's ENVISAT spacecraft. *Matra Marconi Space*

tween the ground and PPF, launch vehicle interfaces and others. These can be tailored to suit the requirements of many missions and payloads.

Power is generated by a solar array which is also modular in design. Its minimum configuration is 8 panels, its maximum 16, the size increasing in discrete steps of two panels. This flexibility in size allows it to be configured to suit the power requirements of the particular payload sets, a 16 panel array having the capability of producing up to 7.5kW at the end of life. Each panel is 1m in length and 5m wide which makes it the largest array wing ever built in Europe. It is attached to the SM and rotates so that it is constantly aligned with the Sun as the satellite orbits the Earth.

The Payload Module

The PLM comprises a Payload Carrier (PLC) and Payload Equipment Bay (PEB), both of which are made of a rigid carbon fibre reinforced plastic/aluminium honeycomb structure. As the name suggests the PLC is the supporting structure on which externally mounted instruments and attitude sensors are located. The PEB houses all the payload support subsystems needed for instrument control, data handling, power distribution, and communications in X and Ka-Band for downlink of payload data. It also contains some of the instrument electronics.

The PLM can be constructed from between two and five discrete segments each 1.6m in length. The number of segments is chosen depending on the size and mass of the set of payloads, a five segment PLM providing 54m² of payload mounting area and the capability of supporting 2400kg of payload mass. Within the PEB, the number of tape recorders, the size of the payload computer memory and the number of communications channels can also be varied to be In line with mission requirements.

The Polar Platform provides two attitude modes for normal operations. In one (Fine Pointing Mode) it maintains 3 axis local vertical pointing, in the other (Yaw Steering Mode) it maintains 3 axis local vertical pointing, as for Fine Pointing Mode, with an additional yaw steering bias of the reference frame to compensate for the apparent drift of the subsatellite point due to rotation of the Earth.

An accurate Attitude and Orbit Control System ensures that the satellite can maintain a very stable attitude for the payloads - pointing accuracy is better than 0.1° while measurement accuracy is better than 0.03°.

During nominal operations the Polar Platform autonomously executes a master timeline uplinked from ground approximately every 24 hours, to provide the necessary instrument mode transitions. Orbit maintenance manoeuvres are initiated from ground and carried out autonomously using data uplinked from ground.

In addition the Polar Platform autonomously monitors itself and switches to redundant functions on detection of a failure.

On detection of a failure for which either no healthy redundant branch is available, or if a switch over does not result in a continuation of nominal operations, the Polar Platform au-

PPF Functional Split

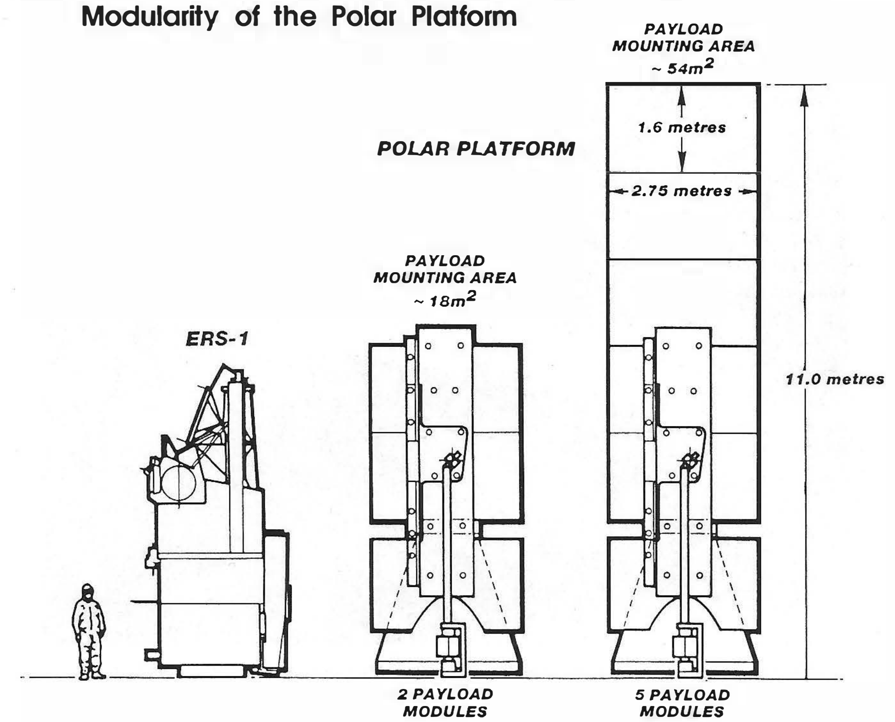
Polar Platform (PPF)

- Payload Module (PLM)
  - PLC
    - Instruments (Externally Mounted) and Antennae
    - Mechanical Support to Instruments and PEB Equipment
    - PLM Interface with the SM
    - Mechanical Support for AOCS Sensors and Thrusters
  - PEB
    - Payload Data Management and Multiplexing
    - Payload Data Communications in X- and Ka-Band
    - Power Distribution for Payloads
    - Thermal Control for Payloads
    - Electrical Interface to Instruments
    - Instrument Electronics (Internally Mounted)
- Service Module (SM)
  - Launcher Interface and Payload Module Support
  - Power Generation, Storage and Distribution
  - Orbit and Attitude Measurement and Control
  - Propulsion
  - Telemetry, Tracking and Command
  - Monitoring and Control of Polar Platform On-Board Operations
  - SM Thermal Control
  - Provision of Pyrotechnic Firing Pulses
  - On-Board Time Generation
  - Instruments (Possibly)

What the Polar Platform Provides

- **a stable support platform with a controlled, suitable attitude**
- **a propulsion capability for maintaining the orbit parameters as necessary for the instruments**
- **a capability for generation, storage and distribution of electrical power required by the instruments**
- **a capability for maintaining a proper thermal environment for the instruments**
- **a capability for receiving commands from ground, storing and routing them to the addressed instruments for changing their operating modes and configurations at the appropriate times and positions in orbit**
- **a capability for collecting, multiplexing and recording the data outputs from the instruments and for transmitting this data to ground stations**

Modularity of the Polar Platform



tonomously switches to a Safe Mode.

The Safe Mode offers a basic survival capability to the Polar Platform and instruments; the Polar Platform can survive autonomously in this mode for several days without ground intervention.

In Safe Mode the attitude of the Polar Platform is controlled such that the nominal Zenith principal axis of inertia is kept sun pointing and the PPF performs a slow rotation about this axis at an angular rate between 0.4 and 0.6 degrees per second.

Recovery from Safe Mode is accomplished by ground command. An S band TM/TC link being provided in this mode to enable the ground to request data, perform fault diagnosis and command the spacecraft.

The Polar Platform is being designed and developed by a European consortium which includes Matra Marconi Space who lead the SM contract, Dornier the PEB contract, CASA the PLM and SM structures and Fokker the solar array. BAe as well as being Prime Contractor also has the responsibility for a number of subsystems and units including thermal control, harnesses, the solar array primary deployment mechanism plus the very complex and technologically advanced multiplexer.

The multiplexer assembly takes low rate instrument data (from 0 to 32 Mbps) directly from the instrument and combines it with the PPF housekeeping data and ancillary data into three different composites. Two of these are for recording and the third for direct downlinking to ground. Up to 15 instrument channels can be accommodated to be input into the multiplexer (including up to 8 with a maximum data rate greater than 10Mbps) providing that the composite data rate does not exceed 50Mbps.

The first mission to use the Polar Platform as a baseline is ENVISAT-1, an environmental mission due to be launched in 1998. A second potential mission is METOP-1, a meteorological mission that would be launched around the year 2000.

ENVISAT-1

The ENVISAT-1 spacecraft is now at an advanced stage with a large amount of hardware and equipments already in manufacture. The mission will consist of 10 payload instruments whose observation parameters will include the distribution of ozone, aerosols and trace gases, their correlation with human activities and their effect on climate. Sea ice and polar ice sheets will be monitored and mapped in terms of their extent and type, snow cover, topography and temperature. Other parameters that can be studied, and charted are the ocean's absorption of carbon dioxide, sea surface temperature, agriculture/forestry,

Europe's Future Plans for Meteorological Forecasts and Environmental Studies

BY THEO PIRARD

Remote sensing from space is taking on increased importance throughout Europe with the development of many more spacecraft to be launched during the next 10 years:

September 1993: SPOT-3 (Matra Marconi Space) identical to SPOT-2, using high-resolution optical sensors, will be placed in sun-synchronous orbit by the 59th Ariane vehicle.

November 1993: Meteosat 6 or MOP-3 (Aerospatiale) is planned for launch in geosynchronous position with the 61th Ariane vehicle.

Late 1994: Helios-1 (Matra Marconi Space + Aerospatiale) will be able able to transmit 1-m resolution photographs for military purposes and will be launched by Ariane 4.

January 1995: ERS-2 (Dornier/Deutsche Aerospace) will be identical to ERS-1 but will carry an enhanced ATSR (Along-Track Scanning Radiometer) with additional visible channels for vegetation monitoring, as well as an atmospheric instrument, the Global Ozone Monitoring (GOME).

1995: MTP-1 (Meteosat Transition Phase) will become Meteosat 7 after its Ariane 4 launch.

1996: SPOT-4 (Matra Marconi Space), compared with the first three, will be a new spacecraft; using a more powerful platform (developed for the military Helios programme). It employs better CCD with infrared capabilities in a pair of HRVIR (High-Resolution Visible InfraRed) sensors.

Mid-1998: Envisat-1 will be an 8-ton remote sensing spacecraft for environmental studies; designed for launch with Ariane 5, it will carry a 2-ton payload consisting of ESA instruments (ASAR, GOMOS, MERIS, MIPAD, RA-2) and nationally funded sensors (British Advanced ATSR, French SCARAB, German SCIAMACHY).

1999: MSG-1 is a 2nd-Generation MOP spacecraft (studied by both Aerospatiale and British Aerospace) which appears to be identical to the existing spin-stabilized satellites.

1999-2000: SPOT-5 will carry an enhanced SPOT-4 payload which would be able to produce stereoscopic 5-m resolution (in monospectral mode) and 60-km swath imagery for mapping activities, together with near-infrared 10-m resolution pictures for vegetation studies.

2000: METOP-1, using the same bus as Envisat-1, is developed under the management of Eumetsat; it will be equipped mainly with instruments designed in the USA (by NOAA and NASA) for meteorological measurements (VIRSR, IRTS, MTS or Microwave Temperature Sounder, MHS or Microwave Humidity Sounder, IASI or Infrared Atmosphere Sounding Interferometer), with Italian MIMR (Multifrequency Imaging Microwave Radiometer), German ASCAT (Advanced Wind Scatterometer), French SCARAB, British sensors, and with a data collection system.

2003: Envisat-2 (British Aerospace Space Systems) will be ready to continue Envisat-1 observations.

2003-2004: SPOT-6 can be identical to SPOT-5.

2005: METOP-2 will be the continuation of METOP-1.

The main problem of these European programmes concerns both the development of new sensors and the funding of ground systems to process the high amount of satellite data at a quick enough rate.

vegetation characteristics and stress, desertification, soil moisture content, sea pollution and coastal erosion.

The ENVISAT-1 spacecraft is made up of four 1.6m PLM blocks which provide $43m^2$ available surface area for payload mounting while supporting up to 2000kg of payload mass.

The ENVISAT-1 spacecraft and payloads weigh approximately 8 tonnes, the spacecraft being about 10 metres in length (comparable to a single decker bus). It will be launched on an Ariane 5 in 1998 from Kourou in French Guiana. Just 20 minutes after lift-off the satellite will reach its operational orbit and separate from the launch vehicle.

Instrument Observation Parameters for ENVISAT-1

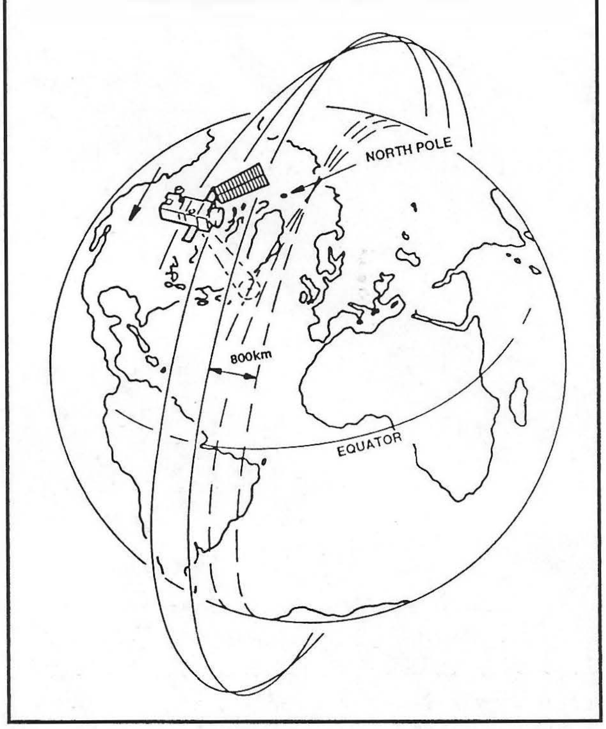
Observation Parameters \ Instruments	ASAR	MERIS	MIPAS	GOMOS	SCARAB	SCIAMACHY	PRAREE	AATSR	RA-2	MWR
Atmosphere										
Clouds		X				X		X		
Humidity										X
Radiative Fluxes		X			X					X
Temperature			X			X				
Trace Gases			X	X		X				
Aerosols		X	X	X		X		X		
Land										
Surface Temperature								X		
Vegetation Characteristics	X	X						X		
Surface Elevation	X								X	
Ocean										
Ocean Colour		X								
Sea Surface Temperature								X		
Surface Topography									X	
Turbidity		X								
Wave Characteristics	X								X	
Wind Field									X	
Marine Geoid									X	
Ice										
Extent	X	X								
Snow Cover	X	X						X		
Topography	X								X	
Temperature								X		

This orbit is a near circular polar orbit to ensure maximum Earth coverage. ENVISAT-1 at an average altitude of 800km will have an orbital period of just over 100 minutes. The other orbit parameters are set to ensure that it is sun-synchronous and has a repeat cycle such that the satellite will fly 501 orbits (just over 35 days) before repeating the flyover of a particular point on the Earth's surface. This allows a fine mapping resolution, especially over the important polar regions. Several instruments with large swath widths give global coverage in just three to five days. In its sun- synchronous orbit, the satellite always passes the equator at a set local time (10am) so that the solar illumination on the surface below is always the same. This is important to instruments with optical sensors as it enables measurements of a specific area made on different days or months to be directly compared. These characteristics together with a 4 year minimum lifetime enable the build up of a very detailed picture of Earth and its environment.

The solar array for ENVISAT-1 is made up of 14 panels, produces 6.5kW and allows up to 4.1kW peak to be delivered to the payloads with 1.9kW average during sunlight or eclipse.

Payload data downlinking and communications with ground is achieved via a network of ground stations located throughout the world. For direct-to-ground links up to 2 X-Band channels each at 100 or 50Mbps can be used. Global capability is extended even further via the use of European Data Relay Satellites (DRS) in geostationary orbit. The link via DRS is at Ka-Band with up to 2 channels available each at 100 or 50Mbps. If required, data can be stored on board (on tape) and played back later when it can be transmitted to Earth at X-Band or Ka-Band. There are four recorders, each with a capacity of 30Gbits, a record rate of 5Mbps and a play-back rate of 50Mbps.

How PPF Builds up a Picture of Earth and its Environment



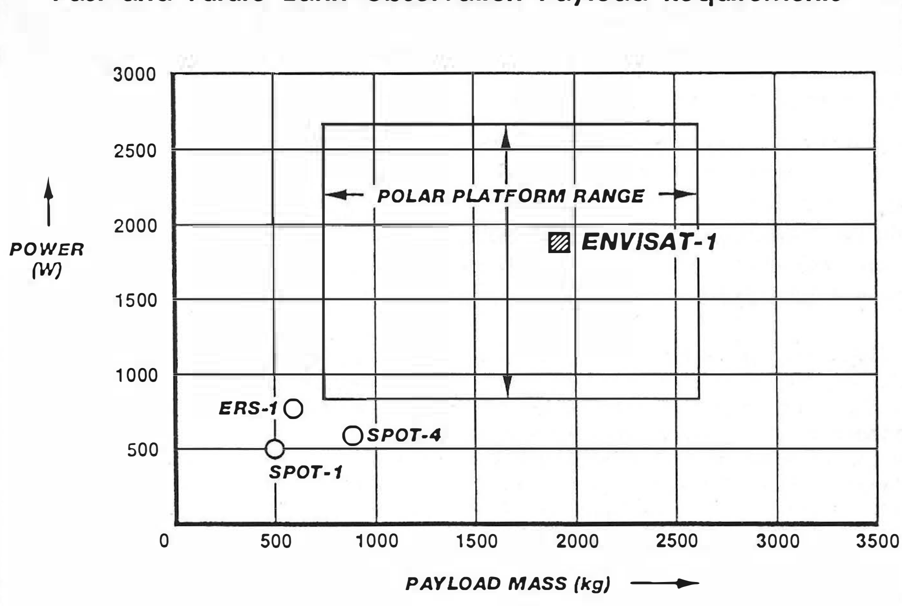
Conclusions

ENVISAT-1 and possible follow on Earth Observation missions for the Polar Platform will be centred around the following major themes:-

- Monitoring and study of the Earth's environment on various scales (local, regional and global)
- Management and monitoring of the Earth's resources, both renewable and non-renewable
- Contribution to the understanding of the structure and dynamics of the Earth's crust and interior
- Continuation and improvement of the services provided to the worldwide operational meteorological community

The Polar Platform has been designed to be modular so it is able to cover all potential Earth observation missions of the future with the minimum of redesign. This enables future work to be concentrated around the development of payloads which will help increase our understanding of the environment and identify human activities and natural processes that threaten its stability and the future of mankind.

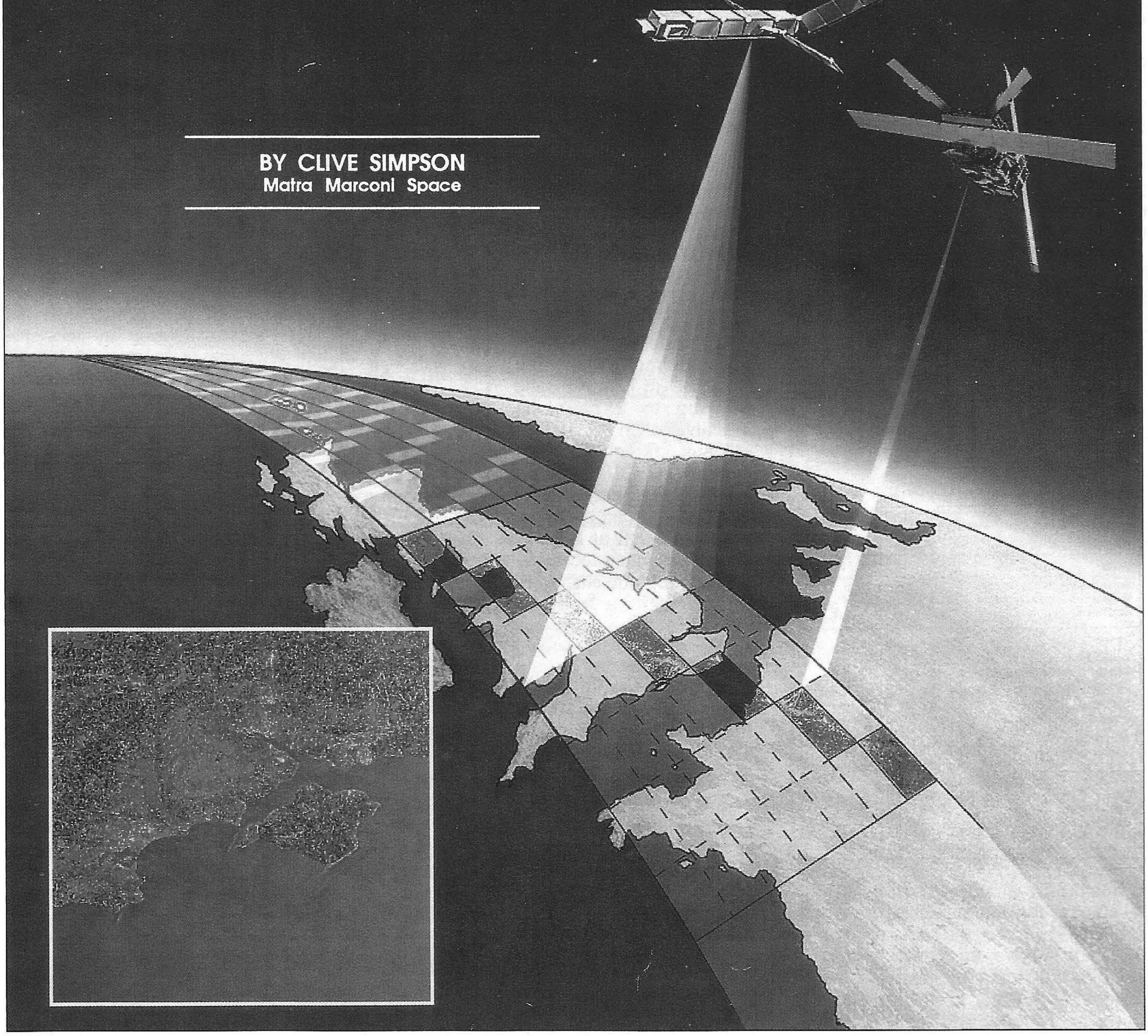
Past and Future Earth Observation Payload Requirements



Advanced Synthetic Aperture Radar

Capturing the Earth's True Images

BY CLIVE SIMPSON
Matra Marconi Space



ERS (SAR) and Envisat (ASAR) comparison. *MMS*

British engineers are designing and building the world's most advanced civil space radar. The Advanced Synthetic Aperture Radar (ASAR), the main instrument on the European Space Agency's Envisat spacecraft, will be manufactured in Portsmouth, UK by Matra Marconi Space (MMS). It will offer the end-user significant advances in reliability, improved images and flexibility in terms of area covered and rapidity of re-visits.

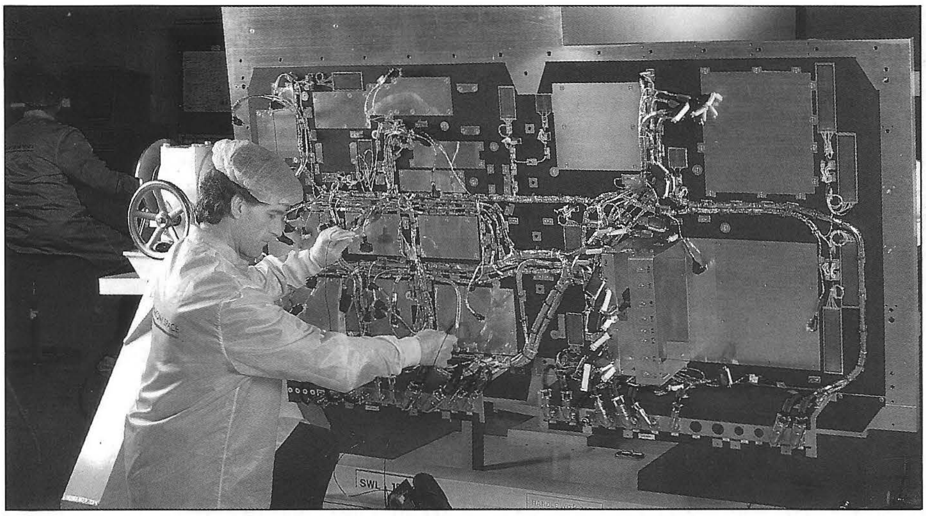
The objectives of the Advanced SAR are very similar to those of ERS-1 and ERS-2. The main task will again be monitoring of the environment in order to collect more precise information on global changes. The key point of interest is the global climate and all possible factors which may have an influence on it, particularly the oceans.

Monitoring of the bio-mass around the Earth, especially monitoring of deforestation in the big primeval forests of the equatorial areas, will allow initiation of counter measures and better modelling of the influence on the greenhouse effect and climate in general.

Desertification and the distribution of humidity, changes in water levels, flooded areas, and the extent of icecaps around the North and South poles are other factors which need to be monitored.

Radar images are already helping to improve our understanding of ocean dynamics, the interaction between the oceans and atmosphere, as well as man-made and natural processes in coastal zones.

A major advantage of using radar for observations of the Earth from space is its capability of recording images in light or dark, independent of cloud cover or adverse weather conditions. This is of vital importance for areas where cloud cover is almost continuous or for disaster assessment - floods or oil spillage, for example, usually



ERS AMI under manufacture at MMS, Portsmouth *MMS*

occur during adverse weather which severely limits the usefulness of optical sensors. A high resolution imaging radar, however, is able to give valuable Information even in poor condltions.

Experience with data from ERS will generally increase the use of radar imagery for operational forecasting. Images from ERS-1 have already proved useful for shipping passing through Arctic ice and, in the future, ocean wave spectra taken around the globe will improve the safety of shipping routes and offshore activities.

Development of radar for Envisat is a result of ESA's success with its first Synthetic Aperture Radar (SAR) on ERS-1, which was launched in July 1991. The SAR, part of the spacecraft's Active Microwave Instrument (AMI), was also built by MMS and has exceeded performance expectations.

ASAR offers significant advantages over the ERS radar and incorporates technological features which will be flown in space for the first time. Key to these is the active distributed electronics phased array antenna. The ASAR transmitters and receivers are distributed across the face of the antenna - some 320 modules In total - instead of being powered by a single transmitter and receiver, as with conventional radar.

Controlling the power and phase of the signals in each of the modules makes the antenna beam steerable, allowing the radar's beam width to be varied and extended towards the horizon - some 700 km from the sub-satellite track. This not only gives the operating authority greater flexibility in choice of image targets, but also the possibility of covering either a narrow swath with high definition or a swath up to 500 km with lesser resolution.

The radar's re-visit time for any location on the globe is thus improved - the coverage of equatorial regions, for example, rises over a nominal three-day repeat cycle from 22 to 100 per cent.

Performance

The ASAR is being designed to meet a prescribed measurement performance derived from ERS performance parameters. It will provide Improved performance compared to ERS, the main areas of note being:

- Ambiguity performance
- Sensitivity
- Radiometric accuracy

The ambiguity calculations and design parameters for ASAR are based on a reflectivity model which is incidence angle dependent and up to 10dB more stringent than the uniform 18dB of ERS. A further constraint, 3dB more severe than the equivalent on ERS, is placed on the ASAR sensitivity. The ASAR also offers significant improvement in radiometric accuracy, with numeric accuracy equal to ERS but with stability improved by a factor of two.

Detailed Design

The design of ASAR incorporates a flexible swath position capability and a second polarisation. The flexible swath position means that, in contrast to the single swath of ERS, the Image Mode of ASAR will offer the choice of seven swaths of various distances from the subsatellite track at incidence angles between 23 and 45 degrees (mid swath). The ASAR will be able to provide data over the range of incidence angles 17 to 60 degrees.

A Second Polarisation means that, in addition to the vertical polarisation of ERS, ASAR will offer a choice of horizontal or vertical polarisation for imaging, or a horizontal/vertical combination. This allows greater spectral data to be available to the user.

Implementation of the Alternating Polarisation Mode will allow half the scans of an image to be acquired in horizontal and half in vertical polarisation. Thus, in a single pass an image of horizontal and vertical polarisation will be taken for the same scene.

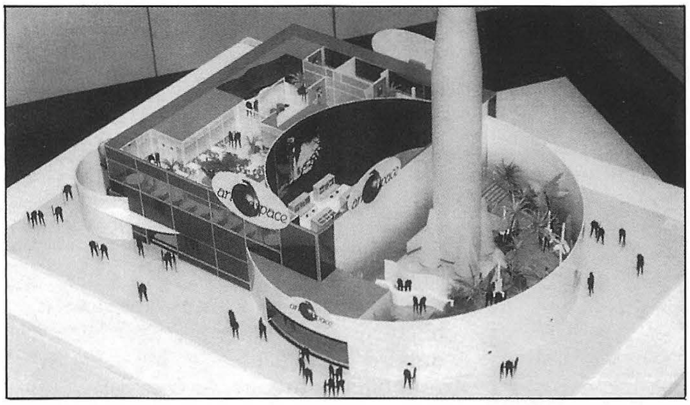
Wide Swath Mode gives ASAR the ability to switch between seven different swaths offering very fast multiplexing so that an overall swath of 500 km width can be imaged in one pass, improving the capability of monitoring large areas.

The Global Monitoring Mode will allow ASAR to operate with a reduced spatial resolution of 1000 m, then the data rate is low enough to store the measurement data on tape onboard the satellite without transmitting directly to the ground. It operates independently of ground station coverage, offering a tool for global monitoring of features such as ice coverage, deforestation, desertification or humidity.

ASAR will also have a wave mode for taking images of 5 km by 5 km, but more frequently in 100 km or 200 km distances over the oceans to supply samples of ocean wave spectra on a global basis.

In summary, ASAR will offer the user significant advantages in reliability, flexibility in terms of the area covered and the rapidity of revisits, plus improved images. These advances in performance enabled by British technology have the assurance and pedigree of ERS-1's flight-proven record.

Processing of ERS-1 data, MMS Portsmouth. *MMS*



Arianespace's pavilion at the 1993 Paris Air Show. Mockup by Maillet SA. *Arianespace*

The Paris

The 1993 Paris Air Show, held from June 11-20, brought together representatives of most of the world's aerospace industries. The show, which welcomed exhibitors from some 38 countries and occupied about 47,000 m² of indoor space, was inaugurated by President Mitterand of France.

The easing of East-West relationships, reduced budgets and the general world recession tended to produce an air of uncertainty expressed by many of the principal exhibitors. The overall attendance was down by almost one third on that of 1991.

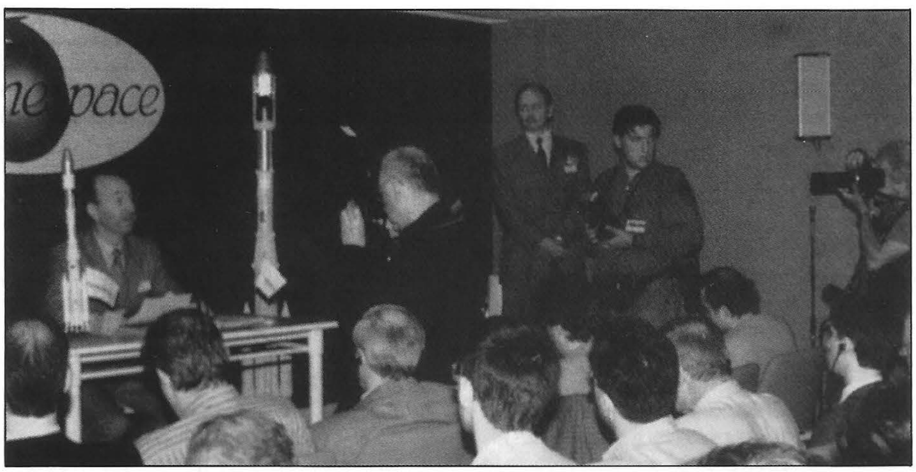
In the field of space, the unsettled environment led to suggestions for cooperation among the established greats - Europe, USA, Japan, Canada and the ex-USSR states - both in unmanned and manned projects. Particularly obvious was the move towards more cooperation between ESA and Russia.

Space-related activities were exhibited by various companies and countries to a greater or lesser degree. The Russian display was considerably reduced over that of previous years and, although the NASA pavilion was not particularly stimulating, it did give an interesting display of space technology and an exciting look toward "unlimited frontiers". Also, certain national pavilions (e.g. Germany, Italy, UK) were not particularly in evidence. The best exhibitions were provided by ESA, CNES and Arianespace.

The European Space Agency (ESA) exhibition was based on three basic themes - Man, Earth and Space. In what was probably ESA's best presentation to date, the central piece was a huge transparent water tank with a model of the Columbus attached laboratory inside, attended by "weightless" astronauts suitably attired for under-water activities. This 360,000 litre water tank was used to illustrate how astronauts train, in weightless conditions, for tasks to be performed in space. Other features of the ESA pavilion included full scale models of current spacecraft, such as ERS-1 and Meteosat, set against a celestial background and a fascinating virtual reality display that allowed the helmet wearer to travel around the outside of a typical space station. Scale models of Ariane 5 and possible payloads were also on show, together with some of the latest data from ERS-1. One day (June 14) was devoted to presentations on ESA programmes - Science, Telecommunications, Ariane 5 and Earth Observations. Two notable events this year that involve ESA are the recovery of Eureca and the repair of the Hubble Space Telescope by a crew of 7 shuttle astronauts including ESA's Claude Nicollier.

At a press breakfast on June 11 ESA's Director General, Dr J-M Luton, explained what ESA is doing in accordance with the three themes previ-

Charles Bigot's press conference at the Paris Air Show. Over 100 journalists attended. *Arianespace*



Appointment of New UK Space Minister

Mr Patrick McLoughlin MP was appointed Parliamentary Under-Secretary of State for Trade and Technology on 27 May 1993.

He has responsibility for research and technology policy, information and manufacturing technology, industrial research establishments, the Department's work on the environment, space, telecommunications, radiocommunications, the Post Office, patents and intellectual property rights.

Roy Gibson Appointment

Mr Roy Gibson, a Fellow of the BIS, has become a Non-Executive Director of the National Remote Sensing Centre Limited (NRSC) Board of Directors. Mr Gibson's appointment came at the request of the British National Space Centre (BNSC) and received the wholehearted support of the NRSC. Mr Gibson will represent the interests of the United Kingdom Government.

Mr Gibson was the first Director General of the European Space Agency (1975-1981) and the first Director General of the British National Space Centre (1985-87). In other years he has been a freelance aerospace consultant to industry, governments and organisations in Europe, Australia and the USA.

ESA Announcements

The ESA Council has decided unanimously to extend the term of office of the Director General, Mr Jean-Marie Luton, to 30 September 1998. Mr Luton was originally appointed for a four-year period from 1 October 1990 to 30 September 1994.

In addition, the Council has appointed Mr Lanfranco Emiliani (Italy) Director of Observation of the Earth and its Environment for four years to replace Mr Philip Goldsmith (UK) whose term of office ends on 31 August 1993.

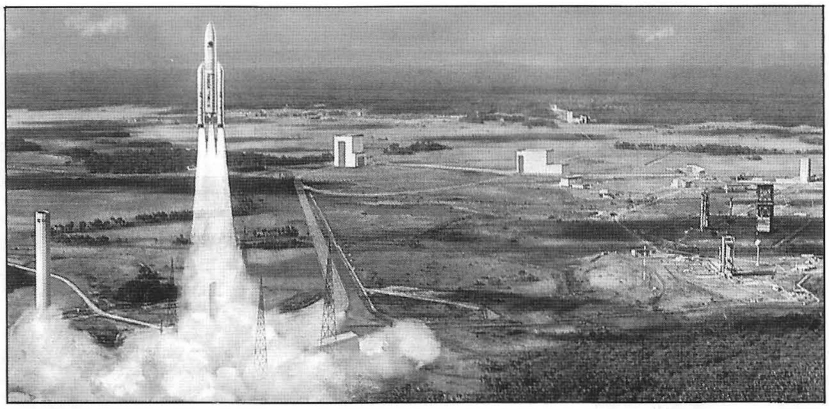
The Council has also unanimously elected its new Chairman for the next two years. Mr Pieter Gaele Winters (Netherlands) will take over from Professor Francesco Carassa (Italy), whose term of office ended on 30 June.

Wedding Bells via INTELSAT

WASHINGTON DC - The Intelsat system brought worldwide coverage of the recent royal wedding in Japan to an estimated one billion people. Intelsat has 19 satellites in orbit around the world and at least four of them handled direct broadcast transmissions from Japan to elsewhere in Asia, Australia, Europe and North America. Planning for world coverage of the royal wedding between Crown Prince Naruhito and Masako Owada took several months. With headquarters in Washington, DC, Intelsat is the international, non-profit commercial cooperative of 125 member nations that owns and operates the global communications satellite system.

Air Show

BY DAI SHAPLAND
Fellow of the BIS



Artist's impression of Ariane 5 lift off from ELA-3 launch pad in Kourou. *ESA*

ously mentioned. He also stated that a particular worry was that the US might choose a Space Station option in its current re-design review, that might exclude ESA cooperation in Freedom. (Note: it has been recently announced by NASA that President Clinton has chosen a compromise modular approach rather than use of the Shuttle External Tank. Even so, the future is not financially secure and possible ESA cooperation on the Russian Mir 2 station and related projects remains a distinct possibility).

The CNES exhibition gave examples of its many fields of interest. These include scientific satellites, Ariane 5, telecommunications, manned spaceflight, the Antares mission and others. It was possible, also, to obtain an overall view of the various CNES facilities such as Kourou from the models and data provided.

The Arianespace Company is in a buoyant mood after capturing more than 50% of the commercial market. M. Bigot, its Director General, gave a press conference at Le Bourget on the company's present position and plans. Success is illustrated by an average of seven launches per year over the past five years and booking of 19 new orders over the past 18 months. Overall, some 40 satellites remain to be launched in the foreseeable future.

The current workhorse is Ariane 4 which will be used until the end of the century. Future operations will be based on Ariane 5 with a first launch set for end-1995. With its capability of launching 5900 kg to GTO, a dual launch configuration is possible leading to important economic advantages. Uncertainty for the future stems from the possible use of Russian, US and Japanese launch vehicles and projected Russian-US link ups, although Arianespace cooperation with Russia and the US is being investigated, in addition to an autonomous European scenario.

The Arianespace pavilion showed models of the Ariane family, presented a realistic firing sequence and even provided information on the launch site flora and fauna.

Water tank for the simulation of space operations - the centrepiece of the ESA pavilion. *ESA*

UK Involvement in Earth Observation

Sugar Beet Monitored

LOGICA, London - The sugar beet industry in Britain and the rest of Europe could make savings of millions of pounds each year through a British Earth Observation space project led by Logica. The British National Space Centre has awarded the project to a consortium led by Logica to develop a sugar beet yield prediction system using a range of satellite data. Working with Logica are British Sugar, Broom's Barn Experimental Station and the University of Nottingham. The £1.8 million project includes a £1.2 million government contribution.

The purpose of the project is to develop a computer-based method to improve the prediction of sugar beet yield. The method will use Landsat, SPOT and ERS-1 satellite data together with meteorological, soil and crop data in a sugar beet yield prediction model. The results will be used by British Sugar to make efficiency improvements in the transport, storage and processing of sugar beet. It should prove possible to achieve earlier and more accurate yield predictions, dramatic reductions in pre-season sampling and improved efficiency through better planning.

Farmland Monitored

FARNBOROUGH, Hants - National Remote Sensing Centre Limited (NRSC) has won a contract to use satellite imagery to help verify claims made by farmers applying for payments under the European Community's Arable Area Payments and Livestock schemes. The contract was awarded to NRSC by the Ministry of Agriculture, Fisheries and Food (MAFF). It represents the largest satellite programme to monitor agriculture ever conducted in the UK.

NRSC will digitise the farm plans and specially trained staff will interpret the satellite imagery to determine both area and land use. The farm plan will be overlaid onto the satellite imagery and what is observed will be compared with what is declared.

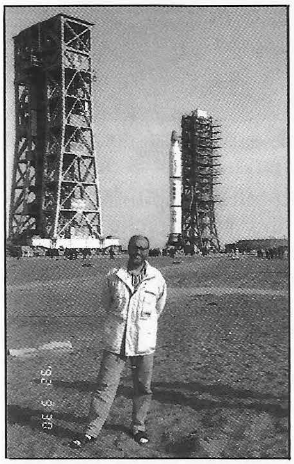
Satellite data from the European SPOT and American Landsat satellites will be used because they offer a high 'spectral' resolution suitable for identifying different types of crop and land use.

Sea Temperature Monitored

VEGA Group plc - Vega is to help with the procurement of a satellite instrument to measure the temperature of the surface of the sea, following the award of a two and a half year contract, worth over £160,000, by the DoE.

The instrument known as the 'Advanced Along-Track Scanning Radiometer' will be launched in 1998 on the ENVISAT-1 environment monitoring satellite, and is being funded by the DoE with contributions from the Australian Space Office, and the National Environment Research Council.

Society News



Sven Grahn in front of the Long March 2C that launched the FREJA satellite. *Supplied by Sven Grahn*

Award to BIS Fellow Sven Grahn

This is the last picture of the FREJA satellite before launch. After the picture was taken on September 25, 1992, the satellite was installed in the so-called "piggyback cabin" of the Long March 2C rocket. From left to right: Mr Gôran Bergman, Mr Sven Grahn, Ms Anna Laurin, Mr Peter Rathsman, Mr Bengt Holmqvist and Mr Gudmund Johansson. The group represents 5 of the 8 members of the FREJA design team. *Supplied by Sven Grahn*

We congratulate Mr Sven Grahn on the award of the 1993 Thulin Medal (silver) for achievements in aerospace engineering by the Swedish Society for Aeronautics and Astronautics.

The Swedish Society cites the important contributions of Mr Grahn in the system design of Sweden's first two satellites; Viking, an auroral research satellite launched by Ariane on 22 February, 1986 and the direct-broadcast TV satellite TELE-X, launched by Ariane on 2 April 1989.

The Swedish Society especially mentions Mr Grahn's work as systems designer and project manager for the FREJA Scientific Satellite, Sweden's third satellite launched on 6 October, 1992 from the Jiuquan Satellite Launch Center in China on a Long March 2C rocket. The FREJA satellite weighs 214 kg and carries seven instruments from four countries for research into the aurora borealis. This satellite has been noted for its exceptional low-cost/high performance profile and the fact that it was designed and built by a very small team. Eight persons designed and five persons assembled and tested the satellite.

Mr Grahn has contributed several articles on Russian space activities in the columns of ***Spaceflight*** and has been an active member since 1966 of the "Kettering Group" of space observers headed by Mr Geoffrey Perry. At the present time Mr Grahn is the director of the Science Systems Division at the head office of the Swedish Space Corporation outside Stockholm, Sweden.

The Thulin Award

Enoch Thulin (1881-1919), after whom the award is named, was a Swedish aeronautical pioneer, aviator and PhD in physics. In 1914 he flew non-stop from Malmoe to Stockholm in 4 hours and 17 minutes! He formed the first aeroplane factory in Sweden, the Thulin Works, in Landskrona in the southernmost county of Sweden. Enoch Thulin perished in an aeroplane crash in 1919.

Results from ERS 1

Dr G.E. Keyte, Defence Research Agency, Farnborough Hants

Evening Lecture to the Society 5 May 1993

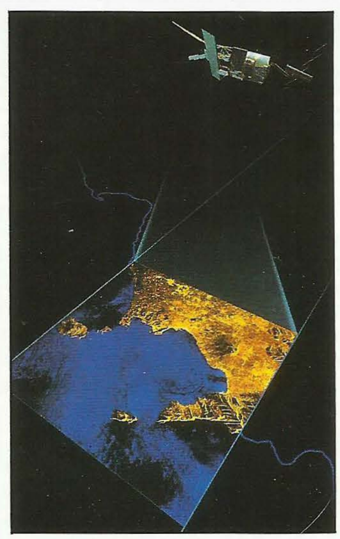
Dr Keyte emphasised the Importance of monitoring our environment and explained the benefits of radar observation at microwave frequencies.

The first European Remote-sensing Satellite (ERS-1) is a large and complex satellite with four primary instruments. The wind scatterometer measures wind speed and direction over the sea with a radar that measures the height and direction of ocean waves. A radar altimeter provides surface height information over land, sea or ice. The largest instrument on board is a synthetic aperture radar (SAR) that uses ground processing of the radar return to build up a high resolution image of a surface swathe 100 km wide. It employs an antenna that spans 11.7 metres. This enables the entire surface of the Earth to be imaged every 35 days. Finally, a UK-build infrared scanning radiometer and a microwave sounder provide information on surface temperature, cloud cover and water vapour in the atmosphere.

The quantity of information returned by the satellite is colossal (105 Mbps from the SAR alone) and an elaborate system of ground stations, computers and administrative systems has been set up to acquire, process and archive the data and supply it to the users. Wind data are sent directly to the Met Office so that it can be used in weather forecasting.

Dr Keyte showed examples of the results obtained and some of the less obvious uses to which they could be put. The SAR resolution was very impressive, with individual electricity pylons visible. The course and speed of ships could be measured and shallow water areas like the Goodwin Sands could be detected from their effect on surface waves. Averaging the altimetry data over oceans provided information on currents and even on ocean depth. The Mid-Atlantic Ridge, for example, showed up well. Oil slicks could be detected and individual tankers observed illegally flushing tanks at sea. The use of radar data to measure crop growth and type was being investigated.

Superimposed on an ERS-1 image of the Bay of Naples is an impression of the satellite in action. *ESA*



Finally, Dr Keyte described European plans for future radar satellite. ERS-1 seems likely to exceed its two-year design life by at least another two years. ERS-2, with identical instruments, will be launched soon and Envisat, with an advanced version of the SAR, will follow in 1998. The bottleneck in processing data resulting from inadequate initial investment in the ground system will be removed and new uses are sure to follow.

G. Richards

Members' Involvement in Media Presentations

Terraforming

Society's Joint Meeting with the University of London

BBC World Service Science Unit and Life on Mars

The first few months of 1993 have provided something like a Spring flowering of media coverage for some of the scientific activities of the BIS and some of its individual members. Following hard on the trail of the recent Horizon and Radio 4 programmes about terraforming is the involvement of a Fellow of the BIS, Richard Taylor of the Centre for Extra-Mural Studies, Birkbeck College in a BBC World Service Science special examining the history of the changing scientific attitudes to the idea that life might exist on Mars.

The impact that the ideas of Percival Lowell had (from the early years of the 20th century to the time of the first Mariner missions on our attitude to the conditions on Mars were as significant psychologically as they were, at first, scientifically. But Lowell was wrong, there is, and probably never was, any advanced form of life on Mars, leave alone the kind of civilisation he imagined.

The programme covers a particularly wide range and the topics discussed include the fundamental question of the origin of life, as well as the possibility that life may have arisen independently on Mars early in the history of the solar system, survived a few hundred million years or so and then became extinct. The idea, still held by some scientists, that living micro-organisms may even now be hanging on to existence on the Red Planet also comes in for examination.

More Media Interest

Media interest in terraforming has continued at a remarkably high level since the first showing of the BBC Horizon film *Mars Alive* on 8 February. Following the recent Weekend School organised jointly by the Birkbeck College Centre for Extra-Mural Studies and the Society, the science section of the *Guardian G2* Supplement included a full three column article concerning the subject of 'Custom Built Planets' by Paul Birch based on his closing presentation at the Weekend School. This was followed up by an 8 minute introductory item on the 10:30 am BBC Radio 5 *AM Alternative* show on 24 May about terraforming in which the Society and a number of members especially active in terraforming research were mentioned. During the previous week Richard Taylor was a contributor to two BBC World Service Programmes, *Science in Action* and a science special entitled *Life on Mars* the subject of life in space and on Mars, both interviews making reference to terraforming. He also took part in a BBC Syndicated Programme *Science Magazine* which is prepared for a number of other overseas countries. This again was about terraforming. Most recently the Horizon film *Mars Alive* was re-broadcast on 2 June. We wonder if this will re-invigorate and maintain the remarkable current level of public interest in terraforming.

'Midweek' Terraforming

The current wave of media interest in the subject of terraforming took a surprising twist on Radio 4 when Libby Purves' *'MidWeek'* programme, broadcast on Wednesday 16 June at 9:05 am, included Paul Birch amongst its guests. The programme is usually devoted to interviews of 'personalities' and celebrities of one kind or another and only very rarely do science and scientists get a hearing on the show. This makes it all the more remarkable that terraforming should have surfaced in the programme. As things turned out Paul was given quite a respectable share of time to explain some of his ideas and to deal with the comments and queries raised by the presenter and other participants in the show. While the emphasis on this occasion was more on the engineering and technologically intense methods rather than the more main stream approach to the subject it succeeded in demonstrating yet again that there is a genuine popular interest in the subject of the longer term future of mankind in space, particularly as an explorer and possible coloniser of new worlds.

Bringing Worlds to Life: Terraforming the New Science of Planetary Environmental Engineering

Organized jointly by the Centre of Extra-Mural Studies, Birkbeck College and the Society a two day school 'Bringing Worlds to Life' was held in the lecture theatre of CEMS at 26 Russell Square, London, over the weekend of the 15-16 May. The meeting broke new ground in at least two ways. It was the first time that the subject of terraforming had been accorded recognition by a UK University as an important area of scientific study. It was also the first time that the Centre and the Society had collaborated in organizing a weekend school with the aim of widening interest in a space-science related subject.

The subjects covered on the opening day ranged from the human impact on the Earth and its environment, to the present environmental conditions of Mars, on to the need for space infrastructure and environmental life support systems that are necessary prerequisites for any attempt to colonize or terraform other planetary bodies. The second day looked specifically at ways in which terraforming Mars might be brought about. Three different possible scenarios for transforming Mars were examined. We started with an exposition of the nearly pure biological approach by increasing the greenhouse effect of the atmosphere by the addition of CFCs. This, it was suggested, would awaken, or revive, processes leading to a slow but progressive and self-sustaining change in the planetary environment towards conditions suitable for plant life but not necessarily for full human habitability. The second talk described how a more technologically intense set of bio-geo-physical techniques could achieve a more rapid and synergistic transformation of Mars into a world fully habitable for humans. The third paper dealt with the most technologically intense solution on offer to the creation of a humanly habitable environment on Mars, the construction of an enclosed environmental system - a Worldhouse.

The school ended with a wide ranging exploration of the limits of the scientifically possible. Given that eventually we achieve the necessary technological competence and the virtually unlimited wealth necessary it appears that we might be able to re-model the entire universe, or at least most of its component parts, according to our own desires.

Society Appoints Deputy Executive Secretary

Suszann Parry

By approval of the Council, Mrs Suszann Parry has been appointed to the position of the Society's Deputy Executive Secretary which has been vacant since February 1991.

Mrs Parry has been in the Society's employment for the last seven years and has a considerable range of experience of Society activities, notably with our meetings and publications. We wish her well in her new position.

Eighth Annual Soviet Space Symposium

One-Day Meeting held at the Society on 12 June 1993

The Symposium was attended by 35 Fellows, Members and friends of the Society who came from Belgium, Holland, Republic of Ireland as well as various parts of the United Kingdom. They participated in looking at a wide variety of programmes from an historic perspective and to update themselves with current news and developments. The topics covered included a review by Dave Shayler of the current cooperation between Russia and the United States using the Mir complex and the US Shuttle. The history of Soviet cosmonautics was explored in papers on the Soviet bio-Sputnik programme from its inception and Obscure Unmanned Satellite Launches presented by Brian Harvey and Phillip Clark.

The potential of Soviet launchers and launching policy was outlined in a number of papers. Stuart Eves looked at the constraints and the commercial possibilities of launching satellites into geostationary orbit. Phillip Clark reviewed the usage and performance of the Block D used on the Proton Booster. New information of the Korolyov design bureau's R9 missile was outlined by Charles Woad.

Anders Hansson discussed some of the current thinking in Russia regarding the value of a Mars mission to collect a sample and return it to Earth. The Symposium also viewed some films including the historic "Steep Roads into Space" and some material from the French/Russian Antares mission of 1992. There was also ample opportunity for questions and discussion especially over lunch which was excellently prepared by Society staff.

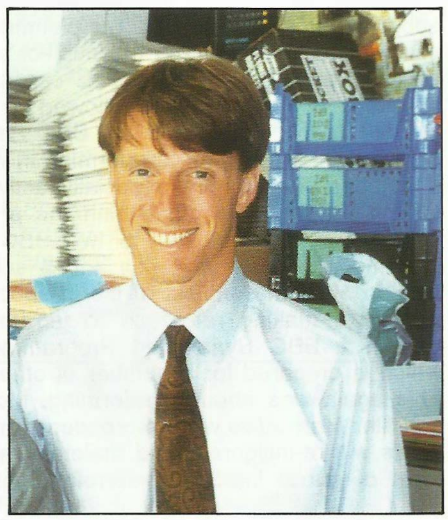
The meeting was chaired by Rex Hall. The 9th Symposium will be held on 4 June 1994. Offers of papers and other materials to be presented at the meeting should be made to the Society.

BIS Stand at Congress Exhibition

The Society will be taking an exhibition stand at the forthcoming 44th International Astronautical Congress to be held at Graz from October 16-23, 1993. Members attending the Congress may like to note this and to visit the stand.

Michael Foale - The All Anglo-American Space Explorer

There are those astronauts who choose to fly in space because it represents the ultimate opportunity to fly higher and faster. Then there are those astronauts who are pragmatic in their outlook, realising that the unique environment of space represents an opportunity to conduct scientific investigations which simply could not be contemplated down here on Earth. Then there are those astronauts such as Michael Foale, who are born with a feel for space running through their veins, and whose actions are driven by a desire to explore other worlds.



Michael Foale in the Space School Office.

BY DARREN L. BURNHAM
Oxford, UK

An Attentive Audience at Space School

Fresh from his second flight aboard the Shuttle just six weeks earlier, the British-born astronaut spoke before an attentive audience of about 200 school-children of his life-long interest in space exploration and the experience of flying aboard the Shuttle. The event was arranged by Brunel University's Space School, and was one of several talks given by Dr Foale during a brief working holiday in the UK which was also an opportunity for him to catch up with his many relatives and friends.

Foale recounted how his interest in space had been galvanised by the sight of Alan Shepard's Mercury capsule on display shortly after its epoch making flight. In hardly no time at all he was mapping out for himself a none too ambitious career plan which envisaged successive trips to Earth orbit, the Moon, and eventually Mars - heady stuff indeed for the son of an RAF pilot growing-up in that most historic of English cities, Cambridge. It was a dream doubtless shared by countless dozens of Foale's generation the length and breadth of the land, for most of whom it was already a lost cause. What set young Michael apart from his compatriots was the fact that his mother was an American, and the dual nationality that this conferred on him kept the door to NASA ever so slightly ajar.

Most of his early actions were driven by the desire to make himself a more eligible candidate for selection as a NASA astronaut. Rejection by the RAF was seen at the time as a mortal blow to his plans, but a Physics degree earned from Cambridge University proved to be a more than acceptable substitute. Flying experience, various outward bound activities, and a job at the Johnson Space Center all followed in succession before he eventually joined the astronaut corps as a Mission Specialist, as a member of the first group of astronauts to be selected after the Challenger disaster.

In his talk, Foale was surprisingly frank about the dangers of space flight. He noted that NASA now estimates that the chance of a fatal accident occurring during a Shuttle launch stands at about one tenth of a percent, remarking that when your turn arrives: "you have faith that this time round it will all be OK".

In Space at Last

After having spent the best portion of his life waiting for the moment, his first flight aboard the Shuttle Atlantis in March 1992, proved to be mildly anti-climatic. His initial reactions were that the Shuttle's orbit was too low, thus restricting the view available. Foale was also surprised to witness the dirtiness of the Earth's atmos-

Rendezvous at Hastings Space '93

The Society's 60th Anniversary is just two months away and so also is the Society's anniversary get together at Hastings, East Sussex on October 15-17.

Now is the time to contact the Society for your Space '93 information pack and to return completed booking forms. Hotel accommodation may be booked through the Society at a special rate subject to availability.

International Space Conference - ISC '93

We are pleased to announce that the Society will be co-sponsoring ISC '93 to be held at College of Aeronautics, Cranfield Institute of Technology on 2-6 August 1993.

ISC '93 is being organised for the benefit of students by SEDS (Students for the Exploration and Development of Space) and the programme of speakers includes several BIS Fellows. Details appear on the inside back cover.

Deke Slayton

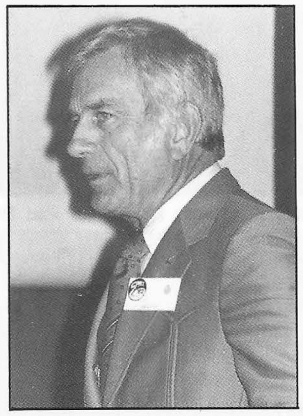
OBITUARY

We regret to report the death of astronaut Deke Slayton, aged 69, who was one of the original 'Mercury 7'. He will be remembered by members who attended the Society's SPACE '82 meeting at Brighton in November 1982 for his forthright and entertaining address about his career as an astronaut.

Picked in the first group of astronauts in April 1959. He was to pilot the Mercury Atlas 7 flight in May 1962. A heart defect caused him to be replaced by M. Scott Carpenter. He fought the grounding and the other astronauts appealed to President John Kennedy to reinstate him. Nothing happened and so he moved in to head the astronaut office, assigning the pilots for each flight and watching his chances of flying in space grow ever dimmer.

But 10 years later doctors said the heart problem had cleared up and he was returned to flight status and was soon named for the Apollo-Soyuz crew. "To some people, life begins at 40," Slayton said at the time. "To me, it's more like 50, but I guess I'd rather be a 50-year-old rookie than a 50-year-old has been". He was the last of the original Mercury astronauts to leave the space programme.

He died at his family home of a brain tumour after a year of treatment.



Deke Slayton

phere at first hand. While there has been a gradual degradation of the view from space since the days of the Mercury and Gemini programmes, the situation had been exacerbated by the sullying effect of the Mount Pinatubo eruption the previous year (the largest volcanic eruption for almost 100 years) which had been responsible for dumping thousands of tons of volcanic ash into the upper atmosphere. It was not long though before the true beauty of the Earth won him over, and he now expresses his unreserved belief that the trip was well worth the wait.

Foale talked in detail about the nine day flight, designated Atlas 1, during which he and his six crew-mates busied themselves by taking a series of measurements which are being used to calibrate the sensors of a number of robotic spacecraft monitoring the Earth's upper atmosphere on a continuous basis (***Spaceflight***, October 1992, p.332-335).

His second flight followed barely 12 months later. Flown aboard the Shuttle Discovery, the main objectives of the mission were a re-flight of several of the Atlas 1 experiments and the deployment of the Spartan satellite which flew independently of the Shuttle for two days in order to observe the Sun. Foale was joined by four other astronauts for what ended up being a nine day long flight. (***Spaceflight***, June 1993, p.198-201).

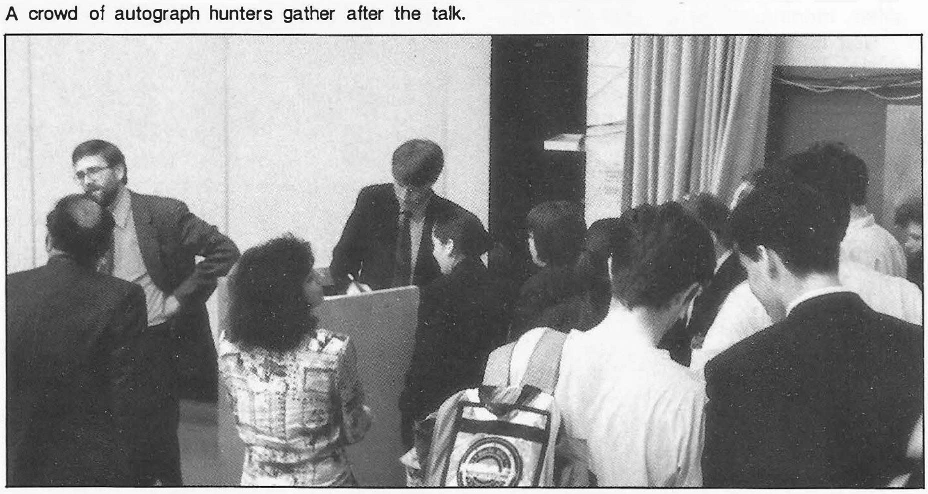
For the future, Foale expects that it will not be too long before he makes his third flight, but after that he may hang-up his flight overalls once and for all. With his eye, as ever, on the future he is drawn to the idea of leaving NASA altogether. His aim now is to work in the private sector on a truly entrepreneurial venture, such as the American Rocket Company's Amroc hybrid rocket. Although presently modest in scale and limited in funds, Foale is convinced that such projects will dictate the pace of activities in space in the next century and beyond.

Although still only in his mid thirties, Foale is clearly saddened that he is now unlikely to go to either the Moon or Mars. Given the chance to go to the Moon he would go without a second thought, but Mars is a different matter altogether. Age has dampened his enthusiasm to some extent, and with a loving wife and a young baby daughter, the ties holding him here to Earth are now much stronger than before. He doubts whether he could summon the will to spend more than two years away from home. Commenting on the arduous journey to and from Mars, he noted that whoever makes the trip: "are going to be people of the most extraordinary character indeed".

Foale has still not lost sight of the initial dreams which first stoked-up his enthusiasm for space flight, and he expressed the hope that he will live to see the day when perhaps his daughter - or at least someone of her generation - sets forth to explore the dusty red plains of Mars.

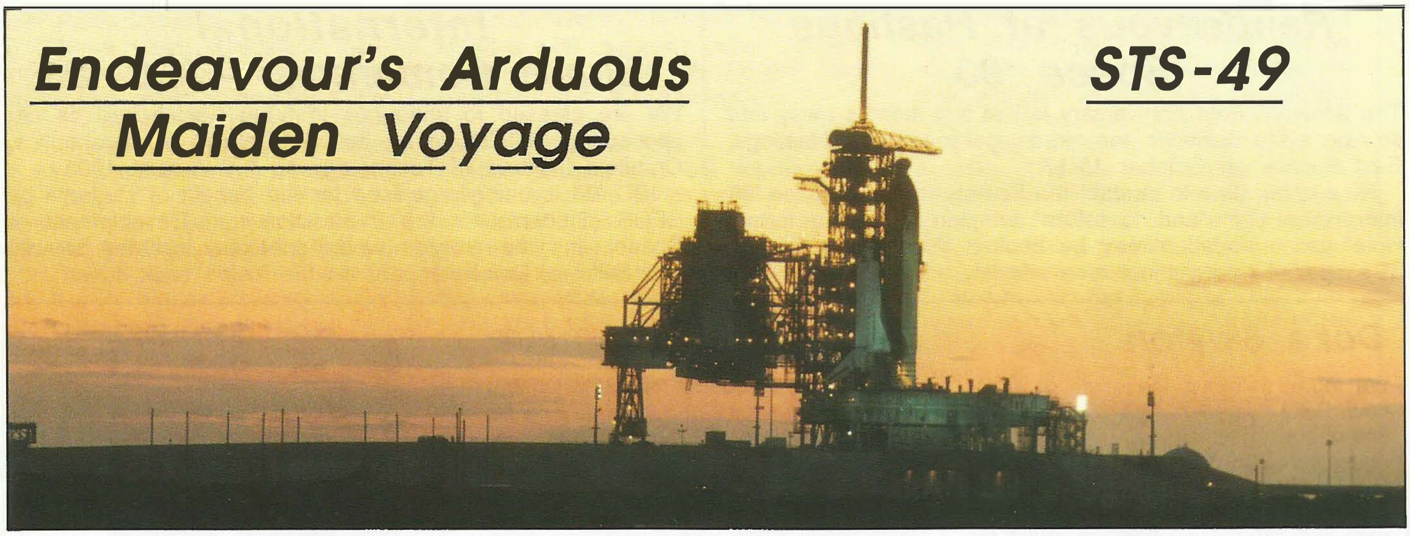
The lasting impression of Michael Foale is that of a man of supreme dignity with an unusually clear vision of the future. In an age when the confines of Earth are forcing most terrestrial bound explorers to become increasingly eccentric in their pursuit of new frontiers to conquer, that is something of which both Britain and America should be justifiably proud.

A crowd of autograph hunters gather after the talk.



Endeavour's Arduous Maiden Voyage

STS-49



Space Shuttle Endeavour on Launch Pad 39B. The Rotating Service Structure (to the left) has been rolled back from the vehicle as the launch countdown proceeds. *NASA*

Success after "Capture" and "Release" Difficulties

The Space Shuttle Endeavour, also known by its NASA orbiter designation number OV-105, was launched on its first space mission at 7:40 pm on the evening of May 7, 1992. Its main mission to attach a perigee kick motor to the INTELSAT-VI communications satellite marooned in low Earth orbit only succeeded at the third attempt with an improvised capture plan.

Endeavour's STS-49 launch came one year, to the day, after it arrived at the Kennedy Space Center. Endeavour was rolled off the assembly floor of the Rockwell International factory in Palmdale, California and placed atop the back of a Shuttle Carrier Aircraft - a Boeing 747 which had been especially modified for such a task - and arrived at KSC on May 7, 1991.

BY ROELOF SCHUILING
at the Kennedy Space Center

Engine Installation and Testing

The new orbiter differed from its earlier sister orbiters in having upgraded avionics systems, modifications and a tail-mounted drag parachute. It underwent extensive testing in the Orbiter Processing Facility (OPF) and had three Space Shuttle Main Engines mounted in its aft compartment. SSME serial 2035 was in the upper or number one position, engine serial 2033 was in number two or lower left position and engine serial 2034 was in the number three or lower right position. These engine systems were then tested and checked out in preparation for the planned Flight Readiness Firing (FRF) test.

The FRF test is undertaken with each new orbiter to bring its verification as close as possible to the real launch conditions. With the exception of firing the Solid Rocket Boosters, an FRF test firing is as close as possible to the "real thing".

After months of preparation, Endeavour was transferred from the OPF to the Vehicle Assembly Building on March 10 to be mated with its External Tank and Solid Rocket Booster. The new orbiter was then moved on March 13 to Launch Complex 39B which had, itself, undergone extensive modifications to bring its capabilities and facilities up to date.

Launch pad operations were similar to those in a normal pad operation with the exception of not installing a payload complement. A mission-like countdown was held and on April 6, 1992 Endeavour's three main engines were ignited and fired for approximately 22 seconds.

Although initially all appeared to have gone as planned, data analysis indicated that engine 1 had experienced a "pop" in the oxidiser pre-burner after shut down and engine 2 had a high vibration level. On April 8 Shuttle program managers decided that the best course of action would be to replace all three Space Shuttle Main Engines. The engines were replaced the following week with the Endeavour still at the launch pad. The new engines were serial 2030 in the number one position, serial 2015 in number two, and serial 2017 in number three.

Payload Installation

During the engine replacement period the STS-49 payloads were transferred to the launch pad and installed in the payload bay. The Intelsat-Retrieval payload had arrived at the Kennedy Space Center's Vertical Processing Facility on February 26, 1992 in preparation for tests and integration into the orbiter. The Intelsat-Retrieval payload consisted of a perigee kick motor in a cradle and handling equipment. The mission called for the motor to be attached to the Intelsat-VI communications satellite, which had been marooned in low Earth orbit following its launch on a Titan expendable launch vehicle on March 14, 1990. The Titan had a malfunction which prevented separation of the satellite and its motors from the expendable launcher. Intelsat managers separated the perigee kick motor from the apogee motor/satellite combination and left the combination in low Earth orbit in the hopes of future repair or salvage.

Intelsat VI before its successful capture. *NASA*

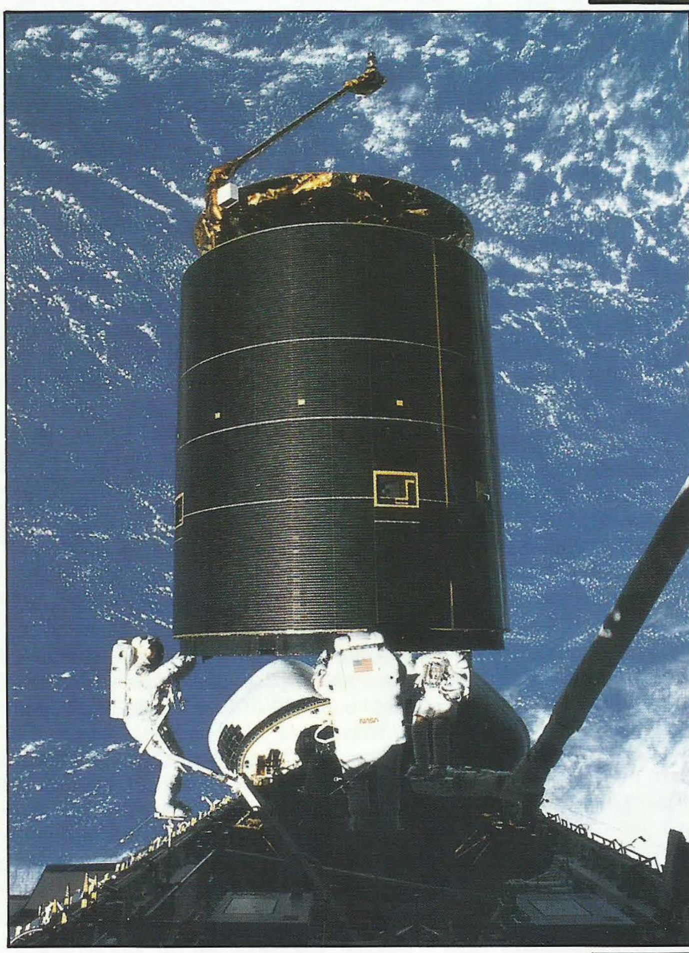
The second STS-49 payload was the Assembly of Space Station by Extravehicular Methods (ASEM) payload. This consisted of a number of rods and connectors with which the STS-49 astronauts hoped to simulate various assembly methods in space. The data that they would obtain from these exercises would help the design of procedures for use in the Space Station era. The ASEM arrived at the VPF on March 5, 1992.

After integration of the ASEM and Intelsat-Retrieval payloads into one payload complement, the payloads were transferred to the launch pad and installed into the Endeavour on April 14. Following tests to verify the interfaces between the Intelsat-Retrieval payload and the orbiter (the ASEM being mechanical, it had no electrical interfaces), a simulated countdown was held on the 16th and 17th of April, in which the actual flight crew participated.

As the newest addition to the Space Shuttle orbiter fleet, Endeavour glides into KSC's Shuttle Landing Facility, Runway 15, on May 7, 1991. It is flying atop the new Shuttle Carrier Aircraft, also making its landing debut at KSC. *NASA*

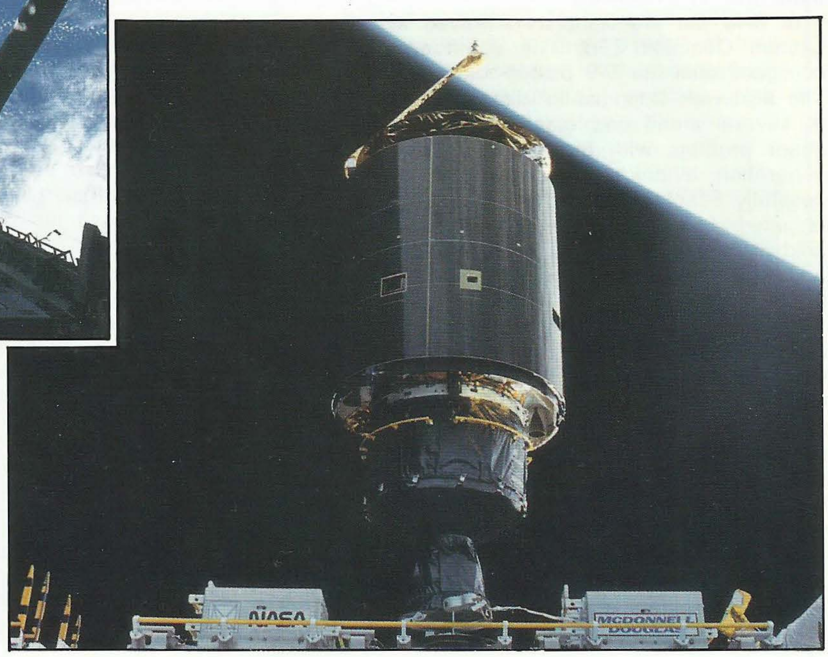
The ship depicted in the patch is HMS Endeavour, the sailing vessel which Captain James Cook commanded on his first scientific expedition to the South Pacific. *NASA*

Right: Mission specialist Pierre J. Thuot manoeuvres a long capture bar device to attempt to snare the errant Intelsat VI communications satellite. He is anchored on a mobile foot restraint attached to the remote manipulator system which is being controlled by astronaut Bruce E. Melnick. *NASA*



Above: The successful capture of Intelsat VI as astronauts (left to right) Richard J. Hieb, Thomas D. Akers and Pierre J. Thuot grasp it with their hands. *NASA*

Below: With its perigee kick motor in place, the 4.5 ton Intelsat VI satellite spins slowly from Endeavour's cargo bay on May 13, 1992. *NASA*



Launch Preparations

The STS-49 Flight Readiness manager's review was held on April 22 and the launch day was picked to be May 4. For this date; however, the launch window would not open until 8:34 pm. As this launch time would place the ascent and possible Return To Launch Site (RTLS) contingency abort operations in darkness, it was decided on April 27 to postpone the launch three days until May 7. As the launch window opened earlier each day, this would place the launch window opening at 7:06 pm when the launch site was still in daylight. The window for the May 7 launch attempt was from 7:06 to 7:55 pm and was largely dictated by the rendezvous with the Intelsat-VI satellite.

Also on April 27, the initial ordnance operations and the pressurisation of the hypergolic propellant tanks took place. These were hazardous operation and only the minimum required personnel were allowed in the area. The following day prelaunch preparation crews resumed their work and the payload was closed out and the payload bay doors were closed for flight. On the 29th and 30th of April purges of the External Tank and the fuel cell reactant supply system were carried out.

The Countdown and Launch

The launch countdown for STS-49 began at the T-43 hour mark at 11:00 pm on May 4, 1992. A series of seven built-in-holds over the next few days were planned to take the count to T-0 at 7:06 pm on the evening of May 7.

Also on the 4th, the flight crew of STS-49 arrived at the KSC site after a flight from their base at the Johnson Space Center in Texas.

The STS-49 countdown continued with no problems through the 4th, 5th and 6th of May. On the morning of the planned launch day there appeared only a 30 percent chance of acceptable weather at launch time. After a mid-morning review of the projected weather, mission managers elected to continue to press on towards the 7:06 pm T-0 time as a clearing trend was in evidence.

At 3:10 pm the flight crew arrived at Launch Complex 39B. The countdown continued until the T-9 built-in-hold point. The hold was extended to allow analysis of several small problems, including a minor problem with the External Tank separation avionics. These were successfully resolved and the count was resumed after a 34 minute delay. A short hold for status at the T-0 point occurred and then the countdown proceeded to T-0 at 7:40 pm.

Liftoff of STS-49 was followed 10 seconds later by the planned roll programme which lasted five seconds. Twenty seconds into the mission the engines were throttled back to 89 percent, and then 69 percent at T plus 32 seconds. At launch plus 59 seconds the three main engines throttled back up to 104 percent. Three seconds later, at 38,000 feet of altitude, STS-49 passed through the maximum dynamic pressure point. Solid Rocket Booster separation occurred on schedule at 2 minutes 5 seconds into the flight and main engine shutdown came at 8 minutes, 30 seconds after launch. Twelve seconds later the External Tank separated from the Endeavour.

May 7-8, 1992

After reaching orbit the mission specialist seats were folded and stowed out of the way in the crew cabin, payload bay doors were opened, the Ku-band/radar antenna was swung out of the payload bay, and orbiter systems and avionics were configured for orbital rather than ascent operations.

About the Crew

The commander of the mission was three-time space flight veteran Daniel C. Brandenstein, Capt. USN, who had served as pilot on STS-8 and commander of STS-51G and STS-32. The mission pilot was Kevin P. Chilton, Lt. Col., USAF, who was making his first flight.

The crew had a total of five mission specialists, all of whom had made one previous flight. Bruce E. Melnick, Cmdr., USCG, had flown on STS-41; Thomas D. Akers, Maj. USAF, had flown on STS-41; Richard J. Hieb had flown on STS-39; Kathryn C. Thornton, PhD, had flown on STS-33; and Pierre J. Thuot, Cmdr., USN, had flown on STS-36.

May 8-9, 1992

Crew activities involved preparations for the upcoming Extra-Vehicular Activity (EVA) operations as the astronauts depressurised Endeavour's cabin to 10.2 psi and performed checkouts of the space suits they would be wearing. The orbiter Remote Manipulator System (RMS) robot arm was also put through checks to insure it would be ready to function during the Intelsat satellite rescue attempt.

Endeavour and the Intelsat satellite both performed orbital manoeuvres by firing their engines. These firings changed the two spacecraft's orbital parameters to initiate a closing operation that would reduce the distance between the two.

May 9-10, 1992

Endeavour and the Intelsat satelliteagain performed firings of their engines to bring the two closer together. At one point they were closing at a rate of 400 miles every orbit. These engine firings also brought the two orbital planes closer together and circularised the orbits.

May 10-11, 1992

The major planned activity for the day had been the capture of the Intelsat satellite and its subsequent deployment. However, the job proved more difficult than expected. Mission specialists Pierre Thuot and Rick Hieb entered the Endeavour airlock at about 3:00 pm after donning their EVA space suits. About ten minutes later they entered the orbiter's payload bay. At that point Endeavour and the Intelsat satellite were separated by approximately eight miles as mission commander Dan Brandenstein flew the orbiter toward its rendezvous.

As the two spacecraft approached each other slowly, Pierre Thuot took up his position at the end of the RMS arm. He was equipped with a bar, termed the "capture bar" equipped with latches which were to grasp the bottom of the satellite. The bar would then be manoeuvred down toward the payload bay where the RMS arm, operated by mission specialist Bruce Melnick, would grasp it and position it atop a Perigee Kick Motor.

As the operation continued, 225 miles above the Earth's surface, the use of the bar proved difficult. When Thuot attempted to place the bar against the satellite, the satellite slid away and began to tumble slowly. Mission commander Brandenstein manoeuvred Endeavour back to a position close to the satellite as Thuot made three more attempts to get into a position to grasp the satellite with the capture bar. However, the satellite was oscillating too much to allow a safe shot at putting the capture bar against its target. Mission managers decided to hold off on the activity until the satellite could be stabilised. Accordingly, Endeavour moved off to a position about 40-60 miles behind Intelsat to allow Intelsat's controllers a chance to dampen out the swaying motion that the satellite was exhibiting.

May 11-12, 1992

The second attempt to capture the Intelsat satellite began with commander Brandenstein performing the complex rendezvous operation. He brought the orbiter to within 35 feet of the satellite in the darkness over Africa at 6:30 pm (KSC time) and then flew close formation with the spacecraft until reaching the daylight over the Pacific Ocean. Again mission specialist Pierre Thuot on the RMS arm, Rick Hieb in the payload bay, and Bruce Melnick operating the RMS arm sought to get the capture bar installed on the satellite. Although Thuot was perfectly aligned, each attempt to touch the satellite with the bar sent it into a tumble or coning motion. Thuot made four more attempts as Brandenstein flew in tight formation with Intelsat over several hours. As the satellite had wound into a flat spin, there was no way to continue at that point. Endeavour was backed away from the satellite and by several hours later the Intelsat controllers had again stabilised their satellite.

May 12-13, 1992

As Endeavour only carried fuel enough for one more rendezvous attempt it determined that careful reassessment was the order of the day. Detailed analysis of the RMS arm, Endeavour's rendezvous capabilities and the experiences of the past few days led to a decision to try a new approach. The crew also were analysing the operation and radioed down a plan to use three astronauts in the payload bay. They proposed that components of the ASEM Space Station assembly technology payload be used to build a triangular structure upon which the three astronauts could stand. The orbiter would then be manoeuvred under the satellite and the three EVA astronauts would grasp the satellite with their gloved hands and sta-

bilise it so the capture bar could be installed. The capture bar contained an RMS grapple fixture so the RMS could then grasp the satellite and move it down into the payload bay. There it would be attached to its Perigee Kick Motor and then deployed.

The plan was a complex one and much of the day and succeeding night was spent on refining the plans and investigating possible contingencies.

May 13-14, 1992

Once again mission commander Dan Brandenstein performed the complex manoeuvres required to bring the two spacecraft together at 7:45 pm over Australia. Final rendezvous operations had to be delayed one orbit, however, due to a software configuration problem. With Endeavour flying close to the Intelsat, the STS-49 crew put the planned operations into action. Mission specialists Rick Hieb, Pierre Thuot and Thomas Akers took up their positions in the orbiter's payload bay. Akers was atop a truss bar from the ASEM payload which he assembled and was in the forward centre position, Thuot was atop the end of the RMS at the left aft position and Hieb was along the right payload bay wall at the right centre position.

At this point the Intelsat was rotating at about 0.2 revolutions per minute and about eight feet above the astronauts. Commander Brandenstein slowly brought the Shuttle orbiter closer to the satellite until it was between the three space-suited astronauts. The three mission specialists assessed the motion of the satellite for a quarter of an hour to determine the best time and place to grasp the Intelsat. Finally, at Hieb's command, the three astronauts grasped the satellite to the cheers of the controllers at Mission Control. Although they now held the satellite, much careful work remained to be done. The astronauts maintained their hold for almost a half orbit before gradually repositioning the satellite so it could be attached to the capture bar. After mission specialist Hieb attached the capture bar across the bottom of the satellite, Bruce Melnick was able to guide the RMS from inside the aft orbiter flight deck. The RMS caught the capture bar's grapple fixture and the satellite was guided down onto the Perigee Kick Motor that would send it on its way after deployment from the Shuttle.

The satellite was attached to the motor and umbilical connections were made between the satellite and motor. The release latches were unlocked and, upon command from the orbiter aft flight deck, powerful springs pushed the satellite-motor combination away from the Endeavour at approximately 0.6 feet per second.

One final complication arose. As mission specialist Kathryn Thornton attempted to send the command to release the satellite, the command failed to work. After trying again with no result the backup system was attempted twice and it too failed to work. A rapid assessment by ground controllers led to a reconfiguration of the electrical switching system that provided power to the deployment mechanism and a quarter hour later Thornton again attempted the deployment - this time successfully. Intelsat and its new motor were on their way.

The crew poses on the flight deck for the traditional inflight photo. Left to right (front) are Kathryn C. Thornton, Thomas D. Akers and Richard J. Hieb and (back) Pierre J. Thuot, Daniel C. Brandenstein, Kevin P. Chilton and Bruce E. Melnick. *NASA*

May 14-15, 1992

After the successful deployment of Intelsat the previous day, the STS-49 crew could now turn their attention to the originally planned activities of the mission. The Assembly of Space Station by Extravehicular Methods (ASEM) payload was a set of trusswork components that were designed to evaluate the use of EVA activities. Mission Specialists Kathryn Thornton and Thomas Akers donned space suits and entered Endeavour's payload bay at 5:30 pm and spent more than six hours in EVA operations. They first assembled a 15 by 15 by 15 foot trusswork structure in the payload bay. The carrier for the trusswork components; a Mission Peculiar Experiment Support Structure (MPESS; pronounced "Empehss" by program personnel) was then moved by mission specialist Melnick who used the RMS arm to position the MPESS along the structure where the EVA astronauts attached the MPESS to the structure.

The day's activities where the first time in the Shuttle program that four EVA operations had been conducted. The ASEM operations had originally been planed for two separate days; however the added EVA operations in support of Intelsat precluded that schedule.

At 1:23 pm the Intelsat Perigee Kick Motor was successfully fired and Intelsat began the transfer orbit which would take it towards its eventual position in space.

May 15-16, 1992

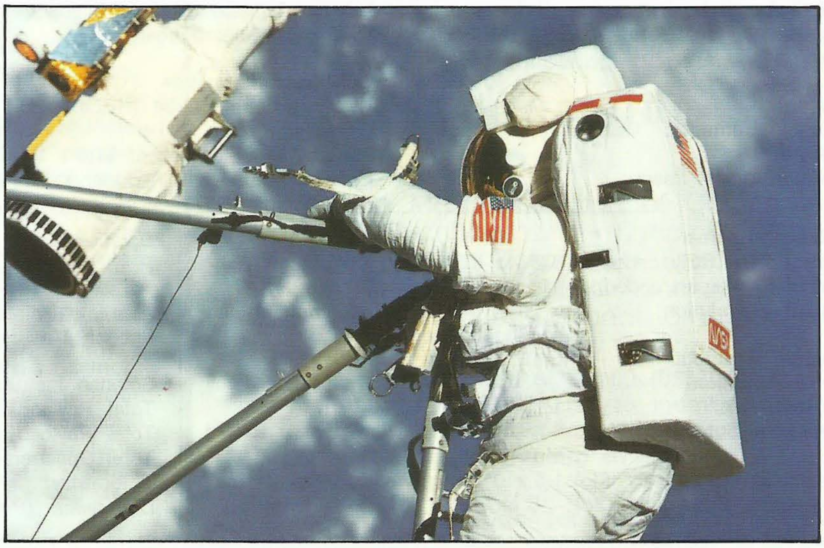
The crew's final complete day in space included the normal end-of-mission operations and the crew began clearing up the cabin and stowing various material for the projected landing.

May 16, 1992

After final stowage and prelanding checks, Endeavour fired its orbital manoeuvring engines to reenter the Earth's atmosphere.

The STS-49 mission came to a close as Endeavour landed at the Edwards Air Force base in California at 6:57:38 pm (KSC time). The mission had been extended two days in order to accomplish mission objectives following the initial problems with the Intelsat capture activity. As Endeavour landed on Edwards' runway 22 the drag parachute that was installed in the orbiter was deployed and tested. This was the first instance of the use of a drag parachute in a Space Shuttle landing and was, therefore, deployed late in the landing as a test of the system's function only. The landing came on orbit 141 after 8 days, 21 hours, 17 minutes, and 38 seconds of mission elapsed time.

Kathryn C. Thornton joins three struts together on the final EVA which was for the evaluation of the Assembly of Space Station by EVA Methods (ASEM). *NASA*



INTEGRAL Confirmed as ESA's Next Scientific Mission

A Truly International Venture

As reported in the last issue of Spaceflight, INTEGRAL (International Gamma-Ray Astrophysics Laboratory) has been confirmed as the second "medium sized" mission within the framework of the "Horizon 2000" scientific programme. In taking this decision ESA's Science Programme Committee not only carried out its scientific duties, but also met the wishes of the Ministers from ESA Member States who had called for more international cooperation at their meeting in Granada in November 1992.

BY NORMAN LONGDON
ESTEC, The Netherlands

The smooth running of the selection process, even though the other candidate missions were all of a commendable high standard, speaks volumes for the advantages of working within a well thought-out framework such as that which "Horizon 2000" provides. I recall that at the time that Roger Bonnet, ESA's Director of Science, put forward the idea, there were arguments that working to an orderly plan would stifle initiative, but events have fully vindicated the introduction of "Horizon 2000". It is also significant that at a time when the way ahead for other programmes is far from clear, the sound footing of the science programmes ensures that they are well supported.

INTEGRAL will be a gamma-ray observatory that will be developed in cooperation with NASA and the Russian Institute for Space Research (IKI). A technical summary of the spacecraft and mission is given in the table below.

INTEGRAL Mission

INTEGRAL addresses the fine spectroscopy and accurate positioning of celestial gamma-ray sources. European and United States astronomers had demonstrated the need for an advanced gamma-ray astronomy facility as a follow-on to the two major gamma-ray missions of the 1990's, GRANAT (which includes the SIGMA instruments) and the Compton Gamma-Ray Observatory. The instruments on board INTEGRAL represent an order of magnitude improvement over the Compton Gamma-Ray Observatory (CGRO) and a major advance on SIGMA.

INTEGRAL will be the first high resolution spectral imager to operate in the gamma-ray region of the electromagnetic spectrum. It will enable detailed measurements to be made of the objects detected by SIGMA and CGRO and therefore to understand them more fully. It is also anticipated that many new objects and phenomena will be discovered. Illustrating how instruments will provide important improvements in spectral and angular resolution.

The scientists involved are confident that, with the highly sensitive instruments on board INTEGRAL which will be 100 times more sensitive than the last high-resolution gamma-ray instruments carried by HEAO-3, the gamma-ray emissions from the galactic plane will be mapped on a wide range of angular scales from arc minutes to degrees in both discrete nucleosynthesis lines and the wideband continuum.

From other measurements it is known that the centre of our galaxy is violently active. INTEGRAL will provide the tools for using gamma-rays as a sensitive probe of the astrophysical processes going on within a few hundred parsec of the nucleus of our galaxy.

INTEGRAL will also study such compact objects such as neutron stars and black holes.

Instruments

Two main instruments will be flown:

- A cooled germanium spectrometer providing high spectral resolution (2 keV at 1 MeV), high line sensitivity, degree mapping of diffuse source emission, and medium (degree) imaging capability;
- A high angular resolution telescope-imager (17' FWHM) providing accurate source positioning, high continuum and good broadline sensitivity, and medium spectral capability.

There will also be two monitor instruments:

- An X-ray monitor (XRM) which will extend the continuous spectral coverage of the payload down to a few keV and will provide the best position information;

INTEGRAL Mission Summary

Objectives
Gamma-Ray Astronomy 15 keV to 10 MeV using High Resolution Spectroscopy and Fine Imaging.
International Collaboration: ESA, NASA, Russia

Payload
Main Instruments: Germanium Spectrometer
Caesium Iodide Imager
Monitors: X-Ray Monitor (XRM), Optical Transient Camera (OTC)
Operational Mode: Observatory
Nominal Mission Lifetime: 2 years
Design Lifetime: 5 years

Orbit and Launcher
Highly Eccentric Orbit (HEO)
Launcher: Proton D 1-e
Period: 72 h, Inclination: 51.6°
Perigee: 48,000 km, Apogee: 115,000 km
or:
Launcher: Titan III/TOS
Period: 48 h, Inclination: 28.5°
Perigee: 4,000 km, Apogee: 117,000 km
or:
launcher: Ariane 5
Period: 24 h, Inclination: 65°
Perigee: 4,000 km, Apogee: 68,000 km

Ground Station
Villafranca, Canberra and/or Goldstone

Instrumentation

Field of View (fully coded):	3.2° to 5.6° (main instruments)
Field of View (part coded):	13° to 22° (main instruments)
Angular Resolution:	< 20' to > 10° (main instruments, according to mode)
Spectral Resolution:	$E/\Delta E \sim 500$ @ 1 MeV
Source Location (20σ source):	1'
Continuum Sensitivity (3σ):	3×10^{-8} ph cm^{-2} s^{-1} keV^{-1} in 10^6 s @ 1 MeV
Narrow Line Sensitivity (3σ):	1.5×10^{-6} ph cm^{-2} s^{-1} in 10^6 s @ 1MeV
Polarization Sensitivity (3σ):	~10 mCrab in 10^6 s, $\phi \sim$ degrees

Spacecraft

Platform:	Three-axis Stabilised Bus Common with XMM
Absolute Pointing Error:	≤ 15' (95%)
Launch Mass:	3643 kg (Proton), 3804 kg (Titan), 3839 kg (Ariane 5)
Science Instrument Mass:	1942 kg
Total Payload Mass:	2314 kg
Total Payload Power:	568 W
Total Spacecraft Power:	1268 W
Telemetry:	40 kbps Science Data
Dimension (Payload):	Diameter: 3 m, Height: 4 m

- An optical transient camera (OTC) which will search for position, and study the optical counterparts of gamma-ray bursts.

Platform

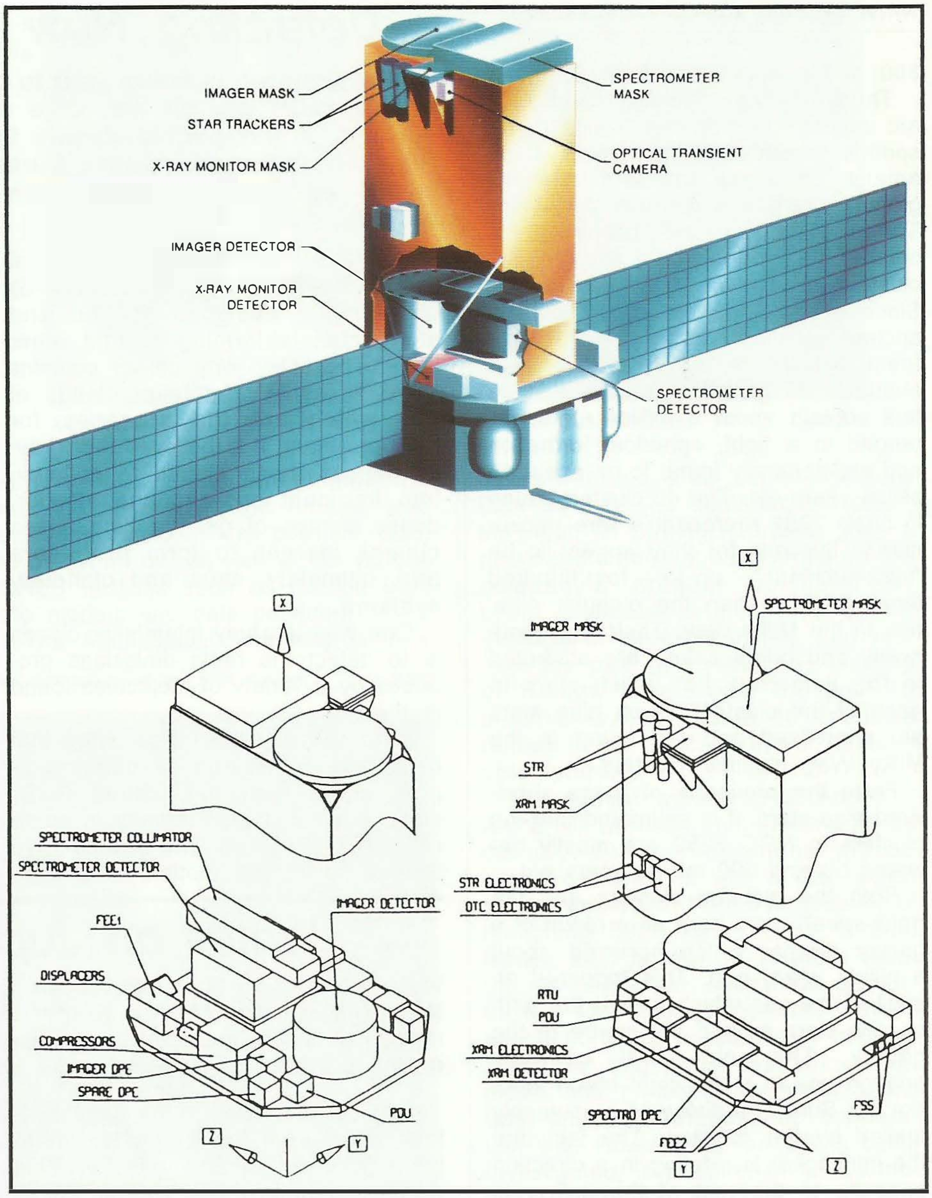
The days of designing each satellite individually are over, and designers now look around to see what is available that can be adapted to specific needs. The platform or "bus" that is to carry XMM is capable of adaptation for INTEGRAL, and so a service module common to the two missions is feasible. Of course the payload hardware and software interfaces are different, but the common "bus" is a cost-conscious approach.

Launchers

It is a sign of the new times that three options can be considered for the launch. The Russian Academy of Science could supply a Proton D 1-e launcher. This is an attractive option for it would enable all observations to be made from outside the radiation belts (the perigee would be higher than 48,000 km). The lift-off mass is high: to achieve a 72-hour orbit with an apogee of 122,000 km, a lift-off capacity of up to 4,260 kg would be needed. At the same time two other options can be considered, a Titan-III launcher equipped with the "Transfer Orbit Stage" supplied by NASA and Ariane-5.

INTEGRAL has much to recommend it, and work will be scheduled to meet a launch date in 2001. The mission will last two years, but if all goes well a lifetime up to five years would be possible.

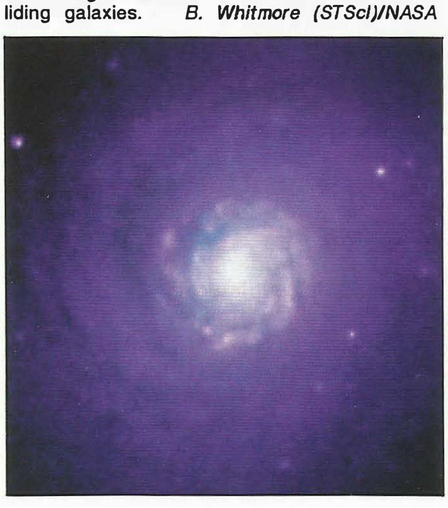
Once again, with limited resources but careful planning, Europe has shown that it can retain its significant role in space science.



Top: The INTEGRAL satellite with the payload module mounted on the service module. A cut-away view shows the science instruments. *Below:* Front and back views of the payload module. *ESA*

Astronomical Notebook

A visible light image (in false colour) of a spiral disk and globular star clusters at the core of colliding galaxies. *B. Whitmore (STScI)/NASA*



When Galaxies Collide ?

NASA's Hubble Space Telescope (HST) has discovered a new population of exceptionally bright and young star clusters at the heart of a head-on collision between two galaxies, as well as a rotating, pinwheel-shaped disk at the centre of the collision. The disk resembles a full spiral galaxy, seen face on, yet it is only ten thousand light-years across, or about 1/20 the diameter of the whole galaxy.

The newly-found clusters are concentrated near the core of the peculiar galaxy NGC 7252 and were apparently born in the aftermath of the collision of the two disk-shaped galaxies which occurred about a billion years ago. These galaxies are now in the process of merging into a single giant elliptical galaxy. The galaxy has a pair of long tails that are unambiguous evidence of the effects of gravitational tidal forces from a galaxy merger. The galaxy is nicknamed the "Atoms-for-Peace" galaxy because its stars form a bizarre loop-like structure that resembles a schematic diagram of electrons orbiting an atomic nucleus.

Though several of the clusters were first spotted from ground-based telescopes, their true nature was uncertain until now.

This discovery provides some of the best evidence to date for explaining the origin of giant elliptical galaxies.

The HST image shows a spiral pattern at the galaxy's core, surrounded by bright star clusters. Hubble observations succeeded in resolving these globular clusters and measuring their apparent sizes in the sky, despite the vast distance of NGC 7252, located in the constellation of Aquarius some

When Galaxies Collide ? (continued)

300 million light-years from Earth.

The clusters are typically about 0.04 arc seconds in diameter, which corresponds to about 60 light-years in diameter, i.e. about the same size as globular clusters in our own Milky Way. Those in NGC 7252 probably resemble the progenitors of the globular clusters in our own Milky Way galaxy. Since such clusters normally contain ancient red giant stars, they provide a fossil record of the formation and evolution of galaxies. Globular clusters contain about a million stars, arranged in a tight, spherical formation and are generally found to be about 15 billion years old. The 40 clusters found in NGC 7252 represent a rare exception to this rule for they appear to be "ultra-luminous" - up to a few hundred times brighter than the globular clusters in the Milky Way. Their high luminosity and bright colour are attributed to the numerous hot bluish stars in each of the clusters. Such blue stars are short-lived and not found in the Milky Way globular clusters.

From the presence of these short-lived blue stars, it is estimated that the clusters in NGC 7252 are mostly between 50 and 500 million years old.

Both the globular clusters and the "mini-spiral" were born as a result of a galaxy merger which occurred about a billion years ago. This triggered an infall of the gas which fuelled the birth of new stars around the centre of the galaxy. The mini-spiral contains enough gas to make eight billion stars like our Sun. The disk was presumably fuelled by the collision. The fact that the mini-spiral is rotating in a direction opposite to the rest of the galaxy is another clear indication that the material originated from a galaxy collision.

In a few billion years the gas in NGC 7252 will be exhausted and the galaxy will look like a normal elliptical galaxy with a small inner disk.

Detecting New Stars and Planets

A new approach is being used to observe the motion of multiple clumps of interstellar gas on the verge of becoming new stars and planetary systems. It was performed with the instruments developed for NASA's High Resolution Microwave Survey (HRMS), now searching for radio signals that may be coming from technological civilisations on planets orbiting distant stars.

HRMS is part of NASA's Toward Other Planetary Systems (TOPS) programme, designed to find and study planets forming around other stars. The Milky Way galaxy contains large, massive interstellar clouds of gas which are the nurseries for newborn stars. It is believed that gravity causes these clouds to collapse into fragment and produce smaller, dense clumps of gas. In time, these clumps merges to form protostars and, ultimately, stars and planetary systems.

One way to study interstellar clouds is to detect the radio emissions produced by a variety of molecules found in them.

It has already been discovered that radio emissions from a carbon-sulphur chain molecule, called CCS, stand out much more clearly in some of these gas clumps. The clumps have little or no internal motion, other than the random motions of individual molecules at very low temperatures (20 degrees K).

The large 230-foot (70-metre) radio telescope at NASA's Deep Space Network in Goldstone, California was used to detect the radio waves in the star-forming clouds in conjunction with the 2 million channel wide-band spectrum analyser that is the heart of the HRMS sky survey system.

The HRMS spectrum analyser was used to separate out the motions of individual clumps of gas with unprecedented velocity resolution. This instrument, used with the large radio telescope, allowed the detection of small scale structure and study of motion in a star-forming region. This is especially important in resolving the questions of how stars form and why some stars form alone, while others form companion systems orbiting each other.

Water on Jupiter's Moon, Io

Water absorption lines have been found in the infrared spectrum of Io by investigators on NASA's Kuiper Airborne Observatory, which has the unique ability to make infrared measurements while flying above about 99% of the Earth's atmospheric water vapour.

Io is the only body in the Solar System, apart from the Earth, known to have intense volcanic activity. This was discovered by the Voyager spacecraft more than a decade ago.

Patches of sulphur and sulphur dioxide frost cover the satellite. The newly-discovered water ice is combined with the more abundant sulphur dioxide ice on the satellite's surface. Io's thin atmosphere consists mainly of gaseous sulphur dioxide but there is still an element of uncertainty about the main components of its surface.

It had been assumed that although most of Jupiter's satellites are covered with water ice, the volcanically active Io had lost all its original water vapour through vaporisation and the escape of surface gas molecules.

Still in the Dark

Unique measurements, based on the first calculations of the orbit of an object outside the Milky Way, support the existence of "dark" matter. From this it has been concluded the Milky Way galaxy contains about 10 times more mass in a gigantic unseen halo at its outer reaches than is contained in its visible stars.

The minutely shifting positions of hundreds of stars have determined the orbit of the Large Magellanic Cloud - our nearest galactic neighbour - around the Milky Way. From the size and speed of the cloud's orbit, the Milky Way is calculated to have a mass equivalent to 600 billion suns, though the objects within it account for 100 billion suns or less.

Douglas Lin, an astronomer at the University of California at Santa Cruz, thinks that a huge halo of dark matter in the Milky Way is devouring the large Magellanic Cloud.

"What we are witnessing is galactic cannibalism in action", he said. The billions of stars in the visible Milky Way form a spiral 120,000 light years wide. Lin's research indicates that, when the halo is included, the Milky Way is five to 13 times wider and five to 10 times heavier than formerly believed.

This had been suspected for some years past, based on less direct evidence i.e. the fact that galaxies rotate faster than can be explained by the amount of visible matter they contain. It is still an open point on what the dark matter actually *is* but it could consist of large Jupiter-like objects, collapsed stars, black holes or exotic subatomic particles.

Without dark matter, the universe would continue to expand but if there is as much unseen matter as many astronomers now suspect, the universe may stop expanding and perhaps even collapse inwards again, billions of years hence.

The new evidence is based on a comparison of pictures of the Large Magellanic Cloud taken in 1974 and 1989 to measure how fast it moves sideways as it orbits the Milky Way. This made it possible to calculate the gravitational pull of the Milky Way, and thus its mass and size, including the unseen halo.

'Age of the Universe' Quest

A team of astronomers working with NASA's Hubble Space Telescope have announced results which are a major step in measuring the Hubble Constant and the age of the universe. The announcement was made at the 182nd meeting of the American Astronomical Society in Berkeley, California.

The astronomers used the Hubble's Wide Field and Planetary Camera to study two star fields in M81. In each field they took 22 twenty-minute exposures spread over 14 months to find Cepheid variable stars and measure their periods and brightness. The team discovered variable stars and measured the distance of the galaxy to be 11 million light-years.

Team member Dr Wendy Freedman of Carnegie institution of Washington said, "In our two observed fields in M81 we have found a total of 32 Cepheids (variable stars). Decades of previous work from the largest ground-based telescopes have only succeeded in measuring periods for two Cepheids. HST's superior resolution and its ability to schedule observations when and where they are required give it a special advantage in this work".

Cepheids are pulsating stars that become alternately brighter and fainter, with periods ranging from 10 to 50 days. Astronomers have known for over 50 years that the periods of these stars precisely predict their total luminous power, which allows their distance to be measured.

Messier 81 is a large spiral galaxy in the constellation Ursa Major. It is a rotating system of gas and stars similar to our own Galaxy, the Milky Way, but approximately twice as massive. This galaxy achieved prominence three months ago when the brightest northern supernova this century was discovered within it.

In the expanding universe, the Hubble Constant is the ratio of the recession velocities of galaxies to their distances. The age of the universe can be estimated from the Hubble Constant. The age is currently thought to lie between 10 and 20 billion years, but a more precise measurement of the Hubble Constant is required to narrow this further.

SPACE PROBE DIARY

Magellan

28 June

The Magellan Transition Experiment to circularise the spacecraft's orbit by lowering it into the top of the Venusian atmosphere to create drag continues. As at June 25, the spacecraft had made 260 atmospheric drag passes and the apoapsis (the furthest point from the planet) had been lowered below 3,286 miles (5,300 km) from its original orbital apoapsis of 5,294 miles (8,540 km).

The spacecraft's closest point to the planet (periapsis) is being maintained at an altitude between 86 to 88 miles (138 to 140 km).

Magellan is also being maintained in a specific corridor on its closest passes to Venus. It is expected that the orbit will be changed sufficiently by August so that only fine-tuning will be needed to achieve the desired, nearly circular orbit required for high-resolution gravity studies of Venus.

This is the first time a spacecraft's orbit has been changed at another planet by "aerobraking", viz using the planet's atmosphere to create drag.

Pioneer 10

June 11

Pioneer 10 continues to send back science data even though the spacecraft is 5½ billion miles from Earth. It takes more than 8 hours for Pioneer 10's radio signals to arrive.

Pioneer 10 left all the known planets behind on June 13, 1983. The 570-pound spacecraft, launched in 1972, had a design life of 21 months but, more than two decades later, it is still moving through deep space at close to 30,000 miles per hour.

Five of the 11 instruments aboard are still sending back data through the spacecraft's 7½ watt radio signal, with about the strength of a home nightlight. Pioneer 10 has transmitted more than 170 billion bits of science data. The signal has the strength of 4-billionths of a trillionth of a watt by the time its signal reaches the football-field-sized antennas of NASA's Deep Space Network.

Pioneer 10 was the first spacecraft to cross the asteroid belt; to fly by Jupiter and return pictures; to chart Jupiter's intense radiation belts; to measure the mass of its four planet-sized moons; to locate the giant planet's magnetic field and to discover that Jupiter is predominantly a liquid planet.

Pioneer 10 is still seeking the boundary between the solar wind and true interstellar space, to search for evidence of a possible 10th planet and for gravity waves to confirm Einstein's Theory of Relativity.

The probe's most important finding is the extent of the Sun's atmosphere, originally thought to end at the orbit of Jupiter or Pluto. Pioneer 10 is ten times that far and still within the solar atmosphere. The solar wind boundary interface with cosmic interstellar gas might be as far away as 9.3 billion miles, compared to Earth's distance from the Sun of 93 million miles.

Pioneer 10's exploration of the outer heliosphere (Sun's atmosphere) and its interface with the interstellar gas is of fundamental scientific importance.

Ulysses

9 June

The Ulysses spacecraft entered unexplored regions of the solar system by crossing into the highest latitude ever achieved relative to the Sun's equator of more than 32 degrees. It is gathering important new information about the Sun and the Solar environment as it continues to journey farther south toward the Sun's southern pole. About a year from now, Ulysses will be 70 degrees south of the Sun's equator and begin its primary mission of exploring the highest solar latitudes.

Ulysses, launched by the space shuttle Discovery in October 1990, used a gravity assist at Jupiter in February 1992 to move out of the ecliptic plane to enter a new course in a highly inclined solar orbit. Its trajectory will bring it over the south pole of the Sun in September 1994, at which time Ulysses will climb to its maximum latitude of slightly more than 80 degrees. Its orbit will then bring the spaceprobe swinging back toward the Sun's equatorial regions, heading for its second high-latitude excursion in mid-1995, this time above the north polar region.

The spacecraft and its scientific instruments are in excellent condition. First results include:

- The first direct detection of neutral helium atoms arriving from interstellar space.
- The measurement of micron-sized dust grains arriving from interstellar space,
- First measurement of singularly charged hydrogen, nitrogen, oxygen and neon ions, entering the heliosphere as interstellar neutral atoms and then becoming ionized.
- The highest resolution measurements to date of the isotopic composition of cosmic ray nuclei.

Voyagers 1 and 2

9 June

Voyagers 1 and 2 are 4.9 billion and 3.7 billion miles, from the Sun, respectively. Radio antennas on the two craft have been recording unidentified intense, low-frequency radio emissions since last August. The emissions have a total power of more than 10 trillion watts and are probably the most powerful radio source in the solar system, though their frequency is too low to be detected from Earth.

The cause could have been the intense solar flares in May and June 1992 which expelled a cloud of electrically-charged particles that outraced the solar wind. The impact of the cloud on the cold interstellar gas at the boundary of the Sun's influence (the heliopause) probably produced the radio waves.

Although the spacecraft will not reach the end of the heliopause for another 15 or 20 years, they have given an idea of its exact location. The upper limit of the heliopause is now thought to lie within 90 to 120 astronomical units from the Sun.

Artist's concept of Hagoromo lunar orbit insertion. *ISAS*

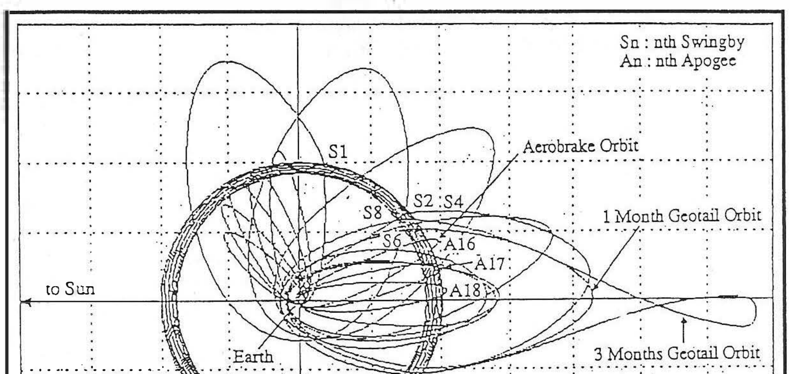
Buddhist Angel's Final Resting Place on Moon

Japan can now well and truly claim to have made a lasting impact on the Moon. Its Hiten spaceprobe crashed on the lunar surface on 10 April 1993, bringing to an end the probe's three-year mission. Although the first few months of the flight were beset by problems, the overall performance of the spacecraft surpassed all expectations by a comfortable margin. As a happy project manager, Professor Kuninori Uesugi, told *Spaceflight* shortly after Hiten's hard landing had been confirmed: "Hiten was named after an angel in Buddhism, who is flying freely and playing music in the heavens, and the spacecraft Hiten has really flown almost as freely in space. Her RIP will not be eternal, because I believe that someday someone will pick her up and bring her back to the Earth. I hope it will happen in my lifetime".

Hagoromo Lunar Orbiter

Hiten was launched by The Institute of Space and Astronautical Science (ISAS) in January 1990 to perform a variety of navigational and engineering tests in cislunar space, the planned highlight being the insertion of the Hagoromo sub-satellite into orbit around the Moon [1]. Although the launch was apparently flawless, the first orbital determination alarmingly revealed that the velocity increment of the Mu-3SII booster had been 50m/sec less that it should have been, leaving Hiten in a much lower orbit than intended. Fortunately, a plan was quickly devised whereby the first lunar flyby could still be achieved by accepting the comparatively modest penalty of adding an extra Earth orbit to the outward journey.

It was while Hiten was winding its way outwards to the Moon that the second major set-back of the mission occurred, with all downlink being lost from the Hagoromo lunar orbiter. This rendered the subsequent placing of Hagoromo in lunar orbit somewhat anti-climatic; but otherwise its impact on the mission was minimal as the 12 kg sub-satellite was not equipped with any scientific experiments. The successful orbital capture took place on March 18, 1990 during Hiten's first lunar flyby, and occurred under the watchful gaze of Earth based astronomers who observed the burn of Hagoromo's solid rocket motor.



Actual trajectory during primary mission phase. *ISAS*

Hiten Demonstrates Aerobraking

Between March and September, Hiten completed a further three lunar flybys. The fifth flyby on October 2, 1990 extended the apogee distance to 1.34 million km, allowing ISAS to use Hiten to simulate the trajectory now being used by its Geotail spacecraft.

The sixth, seventh, and eighth swingbys completed between January and March 1991 were used to reduce Hiten's perigee in preparation for the first of two aerobraking demonstrations in the Earth's upper atmosphere. Although NASA's Atmospheric Explorer's had performed the first aerobraking tests in the mid 1970s, Hiten's flight represented the first occasion on which a spacecraft travelling near to escape velocity had attempted the manoeuvre. Hiten's first encounter with the Earth's upper atmosphere occurred 125 km above the Pacific Ocean on March 19, 1991. The velocity change caused by the atmospheric drag was a mere 1.7 m/sec, but this was sufficient to lower the apogee altitude by 8600 km.

A repeat performance occurred a

few days later on March 30, 1991. On this occasion Hiten's velocity was decreased by 2.8 m/sec, cutting the apogee altitude by about 14,000 km.

The completion of the aerobraking tests brought to an end Hiten's primary mission. In a little more than a year most of the intended objectives had been fully accomplished. However, the tenacious little probe remained in good health, and having used just 75% of its original fuel load, had far from finished its travels. To capitalise on this unexpected bonus, ISAS engineers put their heads together with colleagues from NASA's Jet Propulsion Laboratory to see what possibilities existed for the extended mission.

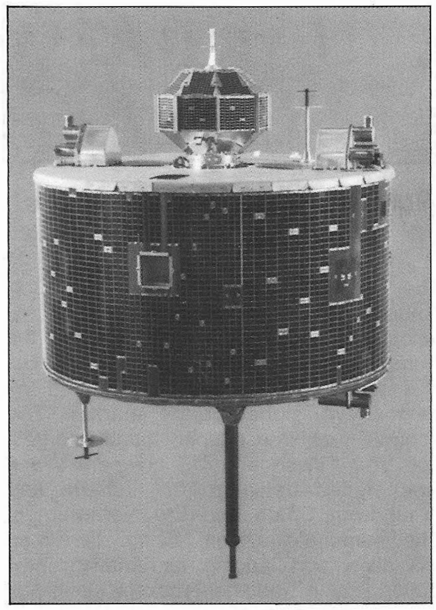
The Follow-On Mission

The first task chosen for Hiten's extended mission was an excursion to the Lagrangian points L4 and L5. At these points - which lie respectively 60 degrees ahead and behind the Moon in its orbit around the Earth - the gravitational influence of the Sun, Earth and Moon cancel each other out, producing a state of stable equilibrium. Given the unique gravitational properties of these two points, it has long been suspected that clouds of micro-meteorites might accumulate there. Hiten was well equipped to investigate this theory, as its solitary scientific instrument was a Meteorite Dust Counter developed by the Technical University of Munich in Germany.

Immediately following the second aerobraking demonstration Hiten was in an orbit with a perigee of 120 km and an apogee of 405,700 km. The ninth lunar swingby in April 1991 - together with several delta V manoeuvres - raised the apogee to a new height of 1,532,100 km. This was followed five months later by the tenth lunar flyby which ensured that Hiten slipped into a looping orbit, taking it around both the L4 and L5 points in turn.

The Dust Counter performed well throughout the excursion, but its findings were somewhat inconclusive. The instrument found no evidence of a significant rise in the number of dust particles populating the region around the L4 and L5 points. However, it remains too early to rule this possibility out entirely simply on the basis of Hiten's data alone, as the spacecraft was able to make only one brief circuit around each point.

With the Lagrange excursion successfully accomplished, the Moon once again became the focus of attention. Previous lunar encounters had been used to alter Hiten's orbit to send it on to far flung destinations, but the eleventh on February 15, 1992, was used to place Hiten itself into lunar orbit. A deceleration manoeuvre of over 80 m/sec enabled Hiten to descend into the Moon's gravitational well, entering an orbit with a perigee of 422 km and apogee of 49,400 km. The successful orbital capture more



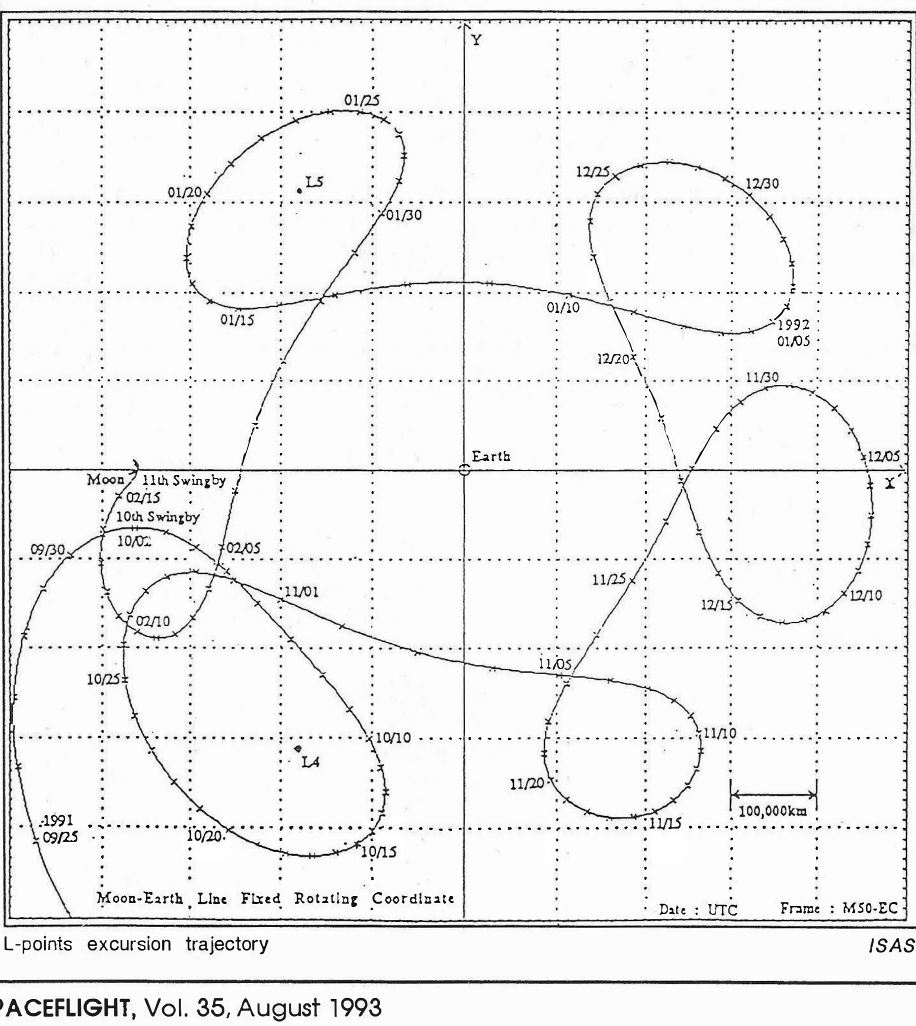
Pre-launch configuration of Hiten and Hagoromo. *ISAS*

than compensated for any disappointment remaining from the moribund Hagoromo two years earlier.

With the exception of a small plane change manoeuvre completed in April 1992, Hiten's orbital parameters were left to their own devices, and slowly but surely the effects of the Moon's gravitational field began to take its toll. By the beginning of 1993, ISAS was predicting that Hiten would eventually crash on the far-side of the Moon on March 28, 1993. The last residual of fuel was, therefore, used to pinpoint a landing site on the near-side; thereby allowing Hiten's demise to be monitored from Earth. Japanese scientists hope to launch the Lunar-A penetrator mission in 1997, and the experience of navigating Hiten to crash land at a predetermined time and place should benefit the team now working on the Lunar-A orbiter and penetrators.

Hiten eventually met its end on April 10, 1993, with communications ceasing just 0.3 seconds earlier than predicted. The crash landing enabled Japan to join a rather exclusive club, for hitherto only the United States and the former Soviet Union could claim to have left a man-made object on the lunar surface.

Japan's next foray into interplanetary space will travel even further afield, for the Planet-B spacecraft will strike out towards Mars during the 1996 launch window.



L-points excursion trajectory *ISAS*

Acknowledgement

With thanks to Professor Kuninori Uesugi. Much of the material for this article was drawn from his paper "Space Odyssey of an Angel - Summary of the Hiten's Three Years Mission" which was presented at the International Symposium on Space Flight Dynamics, co-sponsored by the American Astronautical Society and NASA Goddard Space Flight Center, and held at GSFC between April 26 and 30 1993.

Reference

1. ***Spaceflight***, November 1991, p.370.

Launch Report

Russia to Develop Ariane Landing System

The Russian Research Institute of Parachute Design has won a contract to develop new landing systems for parts of the European Ariane space rocket. The deal is seen as Russia's first big step into the competitive global space market. The contract was won despite tough competition from British and US companies and was signed between the Institute and firms from Spain and the Netherlands. The parachute system being developed will allow soft landing for Ariane's next generation of booster rockets, involving the development of a parachute system capable of carrying a cargo of 35 tonnes.

V57 Puts Galaxy IV in Orbit

On 24 June 1993, Arianespace successfully placed into orbit the Galaxy IV telecommunications satellite for Hughes Communications Inc., USA. Europe's Ariane 42P launcher, equipped with two solid strap-on boosters, lifted off from the ELA 2 launch pad at Kourou, French Guiana at 21:18:00 Kourou time.

Provisional parameters at third stage injection into geostationary orbit were:

Perigee:	199.9 km (±3 km) for a target of 199.8 km
Apogee:	27,668 km (±120 km) for a target of 27,673 km
Inclination:	7.03 deg (±0.05) deg for a target of 7.00 deg

Galaxy IV is the third HS 601 body-stabilised model, developed by Hughes Aircraft Company to be launched by Arianespace. Weighing 2,988 kg (6,574 lb) at launch, Galaxy IV will be positioned above the eastern Pacific and will provide telecommunications, television and data transmission services for more than 13 years.

The next Arianespace launch V58, will use an Ariane 44L to put two telecommunications satellites into orbit: Hispasat 1B for Hispasat of Spain, and Insat 2B for the Indian Space Research Organisation (ISRO).

Commenting on the success of this latest mission, Arianespace Chairman and CEO Charles Bigot said:

> "This evening's launch, initially scheduled for earlier this year, was postponed for further checks, first on the satellite and then the launcher. Tonight's success validates Hughes' and Arianespace's cautious and professional approach during the launch campaign, while illustrating the ongoing reciprocal adaptability between Arianespace and its customers. So see you all again in less than one month for Flight 58!"

SATELLITE DIGEST-255

Satellite Digest is our regular listing of world space launches. It is abridged from a more detailed monthly listing, Worldwide Satellite Launches prepared by Phillip S. Clark and published by the Molniya Space Consultancy.

Spacecraft	Int'l Desig.	Launch	Launch Site	Launch Vehicle	Mass kg	Orbital Epoch	Inclin. deg	Period min	Perigee km	Apogee km	Notes
Cosmos 2245	1993-030A	May 11.63	Plesetsk	Tsyklon	225 ?	May 14.30	82.59	113.95	1,398	1,417	[1]
Cosmos 2246	1993-030B				225 ?	May 14.30	82.58	113.93	1,400	1,418	
Cosmos 2247	1993-030C				225 ?	May 13.35	82.60	114.02	1,404	1,418	
Cosmos 2248	1993-030D				225 ?	May 12.64	82.58	113.99	1,401	1,418	
Cosmos 2249	1993-030E				225 ?	May 13.98	82.58	114.02	1,410	1,412	
Cosmos 2250	1993-030F				225 ?	May 14.38	82.58	113.98	1,399	1,419	
Astra 1C	1993-031A	May 12.04	Kourou	Ariane 42L	2,790	May 19.41	0.02	1,436.22	35,649	35,929	[2]
Arsene	1993-031B				154	May 17.49	1.06	1,027.59	17,666	37,041	[3]
Navstar 20	1993-032A	May 13.01	ER	Delta-2	1,881	May 22.83	54.95	716.05	20,005	20,265	[4]
Resurs-F 17	1993-033A	May 21.42	Plesetsk	Soyuz	6,300 ?	May 22.49	82.57	89.17	230	237	[5]
Progress-M 18	1993-034A	May 22.28	Tyuratam	Soyuz	7,250 ?	May 24.83	51.62	92.36	390	391	[6]
Molniya-1 86	1993-035A	May 26.17	Plesetsk	Molniya	1,600 ?	May 26.19	62.88	736.72	401	40,884	[7]
Gorizont	None	May 27.06	Tyuratam	Proton-4	2,125 ?	Failed to reach orbit					[8]

NOTES

1. Six second generation military field and communications satellites launched on a single booster: co-planar with Cosmos 2211-2216.
2. Luxembourg direct broadcasting satellite: initially located over about 12 °E, to be operational over 19.2 °E. Actual launch time was 00.56 32 seconds GMT.
3. Amateur telecommunications satellite, launched for Radio Amateur Club de l'Espace, France.
4. Eleventh Block 2A Navstar satellite, also known as USA 91. Co-planar with Navstar 19. Actual launch time was 00.07 GMT.
5. Sixth Resurs-F2 flight since missions have not been hidden within the Cosmos programme. Remote sensing mission, to remain in orbit for 30 days. Actual launch time was 09.58 GMT.
6. Cargo freighter, docked at the front end of the Mir Complex May 24.35 (08.25 GMT): for the first time the Mir Complex has two Progress freighters docked (Progress-M 17 is still at the rear end, docked to Kvant 1) as well as the manned Soyuz-TM 16 ferry. Actual launch time was 06.42 GMT.
7. Communications satellite, co-planar with Molniya-1 81: stabilised orbit not attained through to the end of May. Some reports suggested that this satellite was designated "Molniya-1T". Actual launch time was 04.07 GMT.
8. Communications satellite intended to operate in geosynchronous orbit. Second stage of Proton booster failed, preventing orbital injection. Actual launch time was 01.22 GMT.

ADDITIONS AND UPDATES

1977-054A Molniya-1 37 decayed from orbit May 20.

1993-017A Add a new orbit for Navstar 19 (USA 90): Apr 22.22, 54.89°, 717.97 minutes, 20,076 km, 20,288 km.

1993-025A Add a new orbit for Molniya-3 44: May 12.12, 62.85°, 717.94 minutes, 635 km, 39,728 km: satellite is coplanar with and presumably replacing Molniya-3 41.

1993-027A Columbia (STS-55) landed at Edwards Air Force Base May 6.60, 14.29 GMT.

1993-028A At the time of orbital injection there was a major explosion, resulting in 172 fragments being detected. It is unclear whether the explosion was unused propellant on the orbital stage of the launch vehicle, the Cosmos 2243 propulsion system or the premature and accidental operation of the satellite's self-destruct system. The main object after the explosion decayed May 6.

Franco-Russian 21-Day Mir Mission

Baikonur's Future in Doubt

At 6:33 pm Moscow time on 1 July, Soyuz TM-17 was launched on a mission to the Mir space station. Onboard were Vasily Tsibliyev (commander), Alexander Serebrov (engineer) and French researcher Jean-Pierre Haignere.

The cosmonauts are to carry out a new series of tests called "Altair" before Haignere returns on 22 July with the Mir's current crew, Gennady Manakov and Alexander Poleshchuk, who have been in orbit for about five months. The liftoff from the Baikonur cosmodrome was the latest in Russia's effort to fund its struggling space programme with joint space missions and commercial satellite launches.

The space mission is the fourth joint Franco-Russian flight since 1982 and will include three space walks as well as a series of medical and scientific experiments. The French have shown interest in continuing joint flights with the Commonwealth of Independent States and further missions are planned for 1994, 1996, 1998 and 2000.

Baikonur, in central Kazakhstan, is the only cosmodrome in the former Soviet Union equipped to launch manned spacecraft and Russia has been using it since the Soviet Union collapsed in 1991. Moscow wants to turn the cosmodrome into a Russian military base but Kazakhstan opposes this on the grounds that it should have some say since the base is on its territory. Russia has borne the brunt of financing, but more and more people are questioning whether vast sums should continue to poured into the programme when the country is in the grip of an economic crisis.

Russia's Defense Minister Pavel Grachev and his Kazakh counterpart watched the launch from a distance of two miles. The two men had just finished preliminary negotiations on what to do with the former Soviet cosmodrome in Kazakhstan, whose future is now in doubt.

Russia has signalled its intention to carry on with the manned flight programme, saying it would build a new station to replace the ageing Mir-1 whose service life will expire sometime in 1996-1997. The new station, would be ready some time in 1995. Russia and Kazakhstan agreed in February to co-finance this year's running costs of the cosmodrome, which were put at 32 billion roubles ($32 million).

'Mir-2' Being Designed

A new generation space platform is being designed, according to Valery Alaverdov, first Deputy Director General of the Russian Space Agency. The new station will be equipped with a wide range of instruments for practical experiments and fundamental research. The present Mir will be used for space research and cooperation with the US and a US astronaut is expected to fly on it in 1994-1995. Talks are being held on using Russian know-how in maintaining space stations in respect of the US Freedom space station.

Atlantis-Mir Mission

Space shuttle Atlantis will be equipped with Russian docking equipment for its planned linkup with Mir in 1995.

Shuttle builder Rockwell International Corporation will acquire the docking assembly from NPO Energiya of Moscow and install it in an airlock intended for Atlantis. Rockwell and NPO Energiya provided the docking hardware that was used in the 1975 Apollo-Soyuz mission, the only time US and Russian spacecraft have linked in orbit.

The 1995 docking is part of an agreement between the two countries that includes flying Russian cosmonaut Sergei Krikalev on the shuttle Discovery in November (STS-60) and sending an American astronaut to Russia's Mir station for three months in 1994-1995.

STS-57 Mission Success

Weather Delays Launch and Landing

After a final one-day delay due to weather STS-57 was launched on 21 June at 9:07:22 am EDT. Highlight of the planned eight-day mission was the retrieval of Eureca (European Retrievalbe Carrier) which is ESA's science platform that has been in orbit for the last 10 months. After a three-day orbital chase, Endeavour caught up with Eureca and the orbiter's robot arm firmly engaged with Eureca's grapple pin to enable it to be brought into the payload bay. Before the rendezvous, Eureca's huge solar arrays were retracted reducing its span from 20 m to only 4.5 m.

Endeavour touched down at the Kennedy Space Center on 1 July after spending two additional days in orbit due to unsuitable weather conditions at the landing site. Main gear touch down was at 7:52:16 am CDT. Nose gear touchdown was at 7:52:23. The total mission elapsed time was 9 days, 23 hours, 46 minutes and 1 second.

Forthcoming STS Launches

Mission	Launch Target Date	Orbiter Vehicle
STS-51	July 17	Discovery
STS-58	September (second week)	Columbia
STS-60	November 10	Discovery
STS-61	December	Endeavour

New-Generation Arabsats

The Arab Satellite Communications Organization has signed a contract with the Aerospatiale group of France for the supply of two new-generation satellites. The first will be delivered on-orbit in 1996 and the second kept in ground storage.

The second generation of Arabsat satellites, designated Arabsat 2, will continue the mission of the three Arabsat 1 satellites, delivered by Aerospatiale starting in early 1985.

Weighing 2,500 kg (5,500 lb) at liftoff, each satellite has a design life of 16 years and generates 5 kilowatts of electrical power. Arabsat 2 will mark the first use of the new Spacebus 3000 platform developed by Aerospatiale. Alcatel Espace is responsible for the communications payload. The first satellite will be launched by Arianespace, and the French space agency CNES will be in charge of positioning the satellite in geostationary orbit.

To date, Aerospatiale has built or has on order a total of 16 satellites and is the only manufacturer in Europe to have exported satellites outside of the European Community.

Correspondence

SF Enthusiasm

Sir, I have read Mr P.W. Davey's letter (***Spaceflight***, July 1993, p.243) about the lack of Science Fiction films by the BBC. I agree entirely with the letter and could even mention the following further fine examples: "Outland", "Hangar 18" and not to forget the old classic, "The Day the Earth Stood Still".

I am sure that many BIS members were or are very keen SF enthusiasts. It played a large part in stimulating my interest and belief in the possibilities of space flight, starting with the sale of American SF magazines imported into the UK as ballast on cargo-ships and sold on market stalls for 3d (threepence) and with the "Quarterlies" at 6d (sixpence). Although some of the critics of space possibilities were very scathing, a lot of the stories were eventually seen to be only too accurate in their forecast. And why not, some of the authors were actually scientists in their own right.

About that time I found a correspondent in a young man, Arthur Clarke, a student at Taunton Grammar School and actually met him during a touring holiday in Devon, a tousle-haired youth all worked up over science fiction. Then, in 1955 he came to Preston to give a lecture on Space Flight. My wife and I were able to put him up during his stay. The thing I remembered most clearly was the difficulty in getting him down from my library to a meal.

My enthusiasm for science fiction is still very strong, now having a nice collection of what I consider to be the 'cream' of the genre, approaching the 700 mark. I can agree with Mr Davey about the utter lack of it on the BBC.

BERT LEWIS FBIS
Preston, UK

Science Fiction on TV

Sir, Referring to P.W. Davey's letter in the July issue (p.243) and his comments about "not enough SF on the BBC", yes I do tend to agree with his sentiments. However having worked on a good number of the BBC SF series over the years I have now left the BBC - after more years than I care to remember - so I will attempt to look at things a bit more objectively.

The one over-riding problem with science fiction drama for television is that it is very expensive to make; it all has to be specially created. Dramas set in the preset day are consequently cheaper - they do not tend to require vast planetscapes or spaceships! There is also the fact that the audience has got more sophisticated; it has now been weaned on block-busting cinema extravaganzas where money does not appear to be any obstacle. I feel that controllers and heads may have fought shy of commissioning new work in the current climate because of this possible comparison.

Consequently you have the somewhat ironic situation that the only current home-grown BBC SF series is Red Dwarf and this is not even a product of the Drama Department - it is Light Entertainment! But I should also point out that The Children's Department has been involved with a number of recent fantasy series, and they are also making what is generally known as the "Junior Red Dwarf"; Space Vets (on which I am still involved).

Regarding Doctor Who, this always ran separately from any other "scientific SF" series, and it is still the longest-running "SF TV series" anywhere in the world - and every other one has some way to go to catch up - even Star Trek (the original and The Next Generation combined). In theory there should be enough Doctor Who material available to keep re-runs going for a good length of time, though of course here we are into the same problem as in my last series of letters to ***Spaceflight*** - that of video tapes being wiped - and we all know that a good number of Doctor Who episodes have gone that way.

However in recent years the BBC has also produced Moonbase 3; Blake's 7, and then Star Cops (and the latter was not a replacement for Doctor Who at all, if anything it was designed more to fill the Blake's 7 gap).

For a time when Alan Yentob was Controller, BBC-2 almost became a "Sci-Fi Channel" (I personally dislike the term, but it seems to fit here). If I recall correctly over each week you could see - Red Dwarf; Doctor Who; Star Trek - TNG; Thunderbirds, and if you expand the genre to include other related series, Quantum Leap and The Addams Family. Admittedly it is not all home-grown, but you cannot have everything! We also know that SF film seasons always go down well, though it invariably is a result of individual strands within BBC-2 or C4 making the effort. Although here it is certainly more straightforward as all the material is already made.

Yes there is definitely room for a brand new science fiction series for television, I have even had very tentative discussions myself along these lines. But there is one very important final point to be made - if it is done it has to be done right.

MAT IRVINE
Bucks, UK

Government Backing Needed

Sir, Imagine if you will this scenario. The Meteorological Office build a remote sensing weather buoy, at a cost of many millions of pounds, which is to be placed in the middle of the Atlantic Ocean. Having built this device, they then commission the building of a remote controlled vessel, (again at a cost of many millions of pounds) to deliver it to its designated position in the middle of the Atlantic Ocean. Having delivered its precious cargo, the carrier vessel is then abandoned in mid ocean to eventually sink without trace. Two days later, the weather buoy malfunctions and sits uselessly in the water unable to fulfil its designated purpose. To repair or recover it is deemed prohibitively expensive, so the device is abandoned, a monument to the short term outlook of its builders.

A ridiculous scenario? Of course it is! And yet no more ridiculous than the current crazy situation, whereby every year literally billions of pounds worth of equipment are wasted, making one way trips into space. Until this situation is seriously addressed and long term development of fully reusable launching systems, such as HOTOL, SKYLON, SANGER or a NASP type derivative, are undertaken, space utilisation will never achieve its full potential.

This development is far too important (and admittedly expensive) to be left to private enterprise. Financial bodies are of course primarily concerned with their own profitability. The massive long term financial investment required for the development of a fully reusable space transportation system would be totally unjustifiable to a group of investors looking for a short term return on their capital. This initial development will have to be undertaken by governments, and preferably as a collaborative project between a number of countries. Only then will private enterprise be in a position to make use of this technology.

It should also be remembered by those who advocate the "market forces" policy, that not a single penny of private money went into the initial development of the rocket as a device for launching satellites. The rocket was an instrument developed by national governments, as an offensive weapon, and only afterwards diverted to commercial purposes. It is difficult to ascribe the same short term militaristic justification to fully reusable launching systems. What is therefore required from those who have the power to instigate these programmes is something which in the world of real politics seems at times to be sadly lacking, namely a long term vision for the future.

ALAN MARLOW
Bucks, UK

Recovery of Giotto?

Sir, It now appears that Giotto will not be able to perform another comet mission (***Spaceflight***, April 1993) but perhaps someone could tell me if the following would be worthwhile or even possible.

I would like to know if Giotto could be turned into a comet coma/interplanetary dust sample return mission. Since Giotto was not designed for this purpose the quality of the samples returned would be low but given the cancellation of CRAF and Rosetta it would be better than nothing. The primary repository of potential sample materials is probably the dust shield but of course the samples would not be in their original state and would be contaminated by shield material. Also comet coma and interplanetary dust would be mixed together. If it could be shown that the samples would be worth having, Giotto could be brought into Earth orbit by repeated Earth and/or Moon flybys. I base this assertion on the premise that Giotto's present orbit meets the requirements set out in [1], though I am unable to verify this.

It would not be sensible, even if possible, to bring Giotto into too low an orbit because of contamination. Due to this constraint and the long periods required to lower orbits by flyby, an Orbital Manoeuvring Vehicle would be required but in the timeframe considered (1999 onwards) this will hopefully be available.

Aside from science data a further reason for recovery is the engineering data that could help in the design of future comet/interplanetary vehicles.

Doubt has been cast on the ability to reactivate Giotto after so long and if it cannot be reactivated or if insufficient fuel remains for setting up the initial flyby then the above is academic. Even if recovery is possible it will not be cheap (I imagine circa $100-200 million just for vehicles) and given the marginal science return it may still not be cost effective.

J.G. PEARSALL
Rochdale, UK

Reference

1. D.F. Bender, "The Lunar Capture Phase of the Transfer of Asteroidal Material to Earth Orbit by Means of Gravity Assist Trajectories", ***JBIS***, 40, 129-132 (1987).

In response, Neil McBride of the Physics Laboratory, University of Kent, Canterbury writes:

If Giotto were sitting in the lab now, what science could be done? I think the greatest interest would be in terms of research into hypervelocity impacts. There would be a multitude of impact sites to examine from two very different encounter scenarios, i.e. 68 km/s at 90° to the shield, and 14 km/s at 21° to the shield (and hence 69° to the spacecraft sides) so giving information about elliptical craters, penetrating impacts, effectiveness of bumper shield design etc. Because the Halley impacts would be circular due to their normal impact trajectories, and the Grigg-Skjellerup shield craters may be elliptical, it would be likely that the Halley and G/S craters could be largely differentiated. If this were so, then because the impact velocity is known to high accuracy, it would be possible to get a mass distribution of the cometary dust from the distribution of crater sizes. This information could then be compared to the mass distribution information derived from DIDSY data. Also of interest would be to investigate how the spacecraft materials 'weather' due to dust impacts. As far as I am aware, the degradation of solar cell arrays from 14 km/s impacts is not well known.

As for the "dust sample return" science, meteoroids hitting the spacecraft at 68 km/s as at the Halley encounter will have been instantly vaporised. It is very unlikely that we would find 'lumps of a comet' sitting within the spacecraft. However, with ion probe techniques, one would be able to identify minute quantities of materials which were of cometary origin. Perhaps some abundance ratios may be deduced, though I am not sure whether it would yield any more information than was gained from the Dust Mass Spectrometer (PIA) or the Ion Mass Spectrometer (IMS) at the Halley encounter. However, a comparison between the two encounters would be most interesting as PIA and IMS were not operational during the G/S encounter.

Of course in the end, I do not think we shall see Giotto sitting in the lab. I personally do not think the huge cost of recovery vehicles could be justified by the amount of new science that it may produce. Please do spend the money, but spend it on a true cometary nucleus sample return mission, as was initially envisaged for the Rosetta project.

And Richard Flower of British Aerospace Space Systems writes:

The suggestion is certainly novel, but unfortunately is not practical due to the high Earth flyby velocity and the extremely small amount of fuel remaining. The velocity necessary for the Comet Halley intercept was provided by a solid propellant motor (with 374 kg fuel giving 1400 m/s delta V) and must essentially be removed for spacecraft capture; this cannot realistically be achieved with an Earth/Moon flyby scenario. The remaining fuel (4 $\pm$ 3kg hydrazine) is not even sufficient to guarantee a further reactivation, let alone perform any necessary targeting manoeuvres. Independently of the above, significant uncertainties exist as to the availability of a suitable Orbit Manoeuvring Vehicle in the 1999 timeframe and, as noted by the author, costs will be significant.

From Readers of *JBIS*

Sir, I refer to the April 1993 issue of the Journal of the British Interplanetary Society.

I was delighted to find that it had the sub-title "Rocket Technology". I turned the pages and read and read for the next two hours, thinking that only twenty minutes had passed. G.R. Richards and J.W. Powell's article on the Titan-3 and -4 Space Launch Vehicles is the best article published by the BIS for some time, and what we need is more of the same high quality.

My collection includes all of the BIS Spaceflights and most of JBIS from the beginning. Production of articles like these make the subscription completely worthwhile and rewarding. More on rockets please - after all without them we would look pretty stupid.

JOHN PITFIELD FBIS
Dorset, UK

Ed. *Details of the contents of the current issue of **JBIS** appear in Spaceflight each month.* *See p.267.*

Sir, The Journal has helped to fill what would otherwise be an unhealthy gap between those publications dedicated mainly to the minutia of fluid dynamics specialists and those non-quantitative coffee table books and periodicals which, while they tell the story to the general public, are pretty much useless as references.

The Journal's liberal 'let everyone be heard' policy has let thought progress and new ideas get around. The dedicated issues are a real plus in doing research; often I can proceed with one or two open publications on my desk, as opposed to half a dozen scattered all over the place.

GERALD D. NORDLEY
California, USA

Sir, Let me say that your excellent journal is *the best* that I have found at a scientific level. Continue your valuable scientific efforts, you are not alone!

P.A. STONEMANN
Madrid, Spain

Futuristic Designs

Sir, I though ***Spaceflight*** readers might be interested in the design I have just painted on to my new leather waistcoat. It is a version of the NASA logo which I have adapted from some photographs of a model of a 'Space Shuttle Polymorph' design concept by the German industrial designer Luigi Colani.

Unfortunately, despite visiting various bookshops and a trip to the London Design Council, I have been unable to find any more information on either Colani, his shuttle concepts or this NASA logo, which is a pity as his beautiful futuristic designs are not only quite visually stunning but would also, I believe, make for some very interesting reading.

GARY SIMMONS
London

Technology Transfer

Sir, Reinvention of the wheel? Vehicle (1) is Ariane 5 which in 1995 comes full circle as a born-again Vehicle (2) which is a SIVb plus solid fuel boosters of a Titan IIIc, circa 1965.

By examining gross details of Vehicles (1) and (2), the second one being a theoretical combination that could have been built by increasing burn time and fuel capacity of the SIVb core stage by 25 to 30%, it is obvious that the Ariane 5 core stage is the son of the SIVb.

Why has Europe taken 30 years to reinvent and go through a costly development programme? Surely it would have been cheaper to purchase and adapt the technology, manufacturing and equipment rights to the SIVb which the USA so casually discarded when they stopped building Saturn 1B's and 5's.

From the above, why did France/Europe develop the Ariane 1 to 4 in the first place, considering what had been developed and discarded in the USA? Surely some bright spark could have seen the potential of combining these two elements (SIVb + Titan IIIc boosters). If this route had been followed, Ariane 5 would have been an upgraded variant only, saving considerable costs. Thankfully those costs have mostly been borne by the French in developing the Ariane 1 to 5. Gallic pride and politics whatever the costs, coupled with American political arrogance and obsessive secrecy over technology transfer, would probably have prevented a simple idea of just purchasing and re-engineering. Will space ever get off the ground?

If Ariane 5 core is a re-vamped SIVb, then a very interesting prospect arises. Should a heavy lifter become a requirement on an initial return of manned exploration of the Solar System, then two variants of Ariane 5 become possible. Ariane 5 'b' would become the equivalent of the SIVb by reducing fuel capacity and hence length. Ariane 5 'c' would have about half of the amount of fuel or be sized for this amount and suitable to be attached to Energiya or equivalent. Obviously a certain amount of development would be required as no doubt the statements made here are an over-simplification, but redesign should be kept to a minimum and some compromise be accepted. Variants could thus be built on the same production line with a minimum disruption and financial outlay.

ROY L. HARVEY
Hampshire, UK

HOTOL's Wide Market

Sir, Could we correct an assertion in Mr Pearsall's letter in the July 1993 ***Spaceflight***, p.241 . He states that "HOTOL gained its cost advantage to a very large extent by going for a tightly targeted market segment, communications satellite delivery into LEO. It is not clear that this cost advantage will carry over to the use of spaceplanes of this type in other markets".

This is wrong in every respect. While Arianes 1 to 4 were carefully (and correctly) targeted at this market, the HOTOL team were aware that a future system would have to deal with a much wider market including low Earth orbit applications. HOTOL's cost advantage was achieved by reusability and careful design of operations activities. These advantages apply to all payloads, in fact communications satellites actually get the least benefit from HOTOL type vehicles as they need additional propulsion to reach their final geostationary orbit.

HOTOL was never "targeted" at a specific market segment. Early studies during the system sizing gave us confidence that 85% of all payloads could be accommodated unaltered by HOTOL's target capability. Of the remaining 15% most were segments of space stations which could be redesigned for the smaller payload bay. Thus HOTOL was designed as a general purpose launch system designed to carry everything from satellites to astronauts.

We believe there are two reasons why people have been confused over HOTOL's objectives. Firstly much of the publicity material on HOTOL emphasised the more mundane jobs like launching communication satellite. This was because it was the mundane jobs that were British Aerospace's prime business and were the most relevant to the people the publicity was aimed at. Clearly a future launch vehicle that cannot service the applications market segments competitively could hardly be argued as a good investment.

The second reason many people have been confused seems to be the technical decision to operate HOTOL unmanned for most missions. From this they have concluded (incorrectly) that HOTOL cannot carry men and this was never intended as part of HOTOL's role. Nothing could be further from the truth. As we reported at SPACE '90, British Aerospace did a considerable amount of work exploring the support of manned space stations and Lunar bases. This work concluded that a vehicle like HOTOL operating as part of a manned infrastructure is essential to fulfil the real potential of space.

We hope this helps to clear up this widely held misunderstanding about HOTOL's intended role.

C.M. HEMPSELL and R.C. PARKINSON
Bristol, UK

Support for BNSC

Sir, In my letter (***Spaceflight***, July 1993, p.243) I mentioned that I intended to write to the Parliamentary Space Committee to take issue with the comments of a letter in *The Times* from a Mr Miles calling for the abolition of the British National Space Centre as a way of reducing public expenditure.

Sir Michael Marshall has replied:

> Mr Miles also wrote to me and I have drawn the attention of both the Industrial and Parliamentary members of our Committee to his comments. I think the best indication I can give you of our attitude is to tell you that we were involved in a joint work programme with the BNSC at the Paris Airshow a few days ago. Moreover, we will be meeting the BNSC together with the new Space Minister to discuss their future work programme at a session which is planned to take place as soon as the House of Commons returns from the Summer Recess.

P.W. Davey
Dorset, UK

We are Alone

Sir, Many years ago when I read Walter Sullivan's "We are not alone" there was no doubt in my mind about the existence of ETI (Extra Terrestrial Intellligence) and that SETI that is "Search" for ETI had to be carried out at all costs.

Now in retrospect it seems all arguments in favour of multitudes of intelligent populations were based on the "rule of mediocracy", which went something like this: To assume that we are the only intelligent life forms in the galaxy is akin to much self-centredness and conceit, because there are so many star systems even in our own galaxy. First we removed the Earth from the centre of the Solar System, then we placed the Solar System into the outskirts of the galaxy and now we know there is no centre of the universe, making our galaxy average. But this only means we are not at a preferred spacial location.

During the last forty years we have made no progress in determining what percentage of stars might have any planets suitable for life or planetary systems at all. We also have not learned anything new about how and where life might arise.

Once life has arisen, does it necessarily lead to:

1. Multicellular structures like plants and animals
2. Self-conscious, minded, intelligent beings like *homo sapiens*
3. Environment conquering and modifying societies
4. Technological civilisations inventing wheel and metallurgy
5. Scientific discoveries like astronomy and electricity?

I feel that assuming the five steps to be inevitable is like expressing a belief in a religious foundation of the evolutionary ladder.

There is no rational, logical non-theological reason to postulate that any species has a higher level of value in being. Therefore life cannot have a purpose *per se* but its existence is likely to be tied up with a function of utilising and degrading greater energy packets into smaller energy parcels like heat.

Considering that unicellular life existed on Earth for over three billion years before multicellular structures appeared about 700 million years ago, the transition may well be regarded as a very fortuitus occurrence ("accident") seen from our perspective.

We are quite certain also that the invention of the wheel and the discovery of the smelting of metals occurred once only in *homo sapiens'* history: seven thousand years ago in western Asia.

David Hume in his ranking of physical sciences pointed out that it was astronomy that first achieved exactness. The superiority of (modern) exact science over (ancient) science rests on the fact that it asked not only how but how much, making mathematics its essential tool. The invention of exact science also happened only once: five hundred years ago in Europe.

The only ETI radio transmissions we could receive and understand must be at least at the level of our own science and technology level. It is not reasonable to assume that another ETI would have reached the same stage of development at the same time as us, as they would probably have done so a long time ago and would be far advanced in attracting interstellar attention. Since no obvious signals from ETIs have been observed, we may conclude they do not exist.

There is finally the problem of recognising ETI messages. Even if we tuned in on the precise radio wavelength of a sender, it is very far from certain that we could distinguish deliberate artificial transmissions from random radio noise receptions. Please observe: Unless we understand a language it is impossible to decide if a voice over the telephone is conveying meaning or gibberish.

Thus I suspect SETI by scanning stars for "meaningful" radio transmissions is futile. If we ever come across evidence of ETI it will result from an unrelated unpredictable astronomical study.

True - we can never be certain that ETI does not exist. But until we find evidence for it: I shall consider absence of evidence as evidence of absence of ETI and that "We are alone".

GEORGE OEFNER
Ontario, Canada

Space Shuttle Competition

Spaceflight's competiton this month highlights one of the Space Shuttle's most arduous missions, STS-49, in which the orbiter Endeavour flew for the first time.

Six video prizes: 'STS-49 Mission Highlights' will be the prize for each of the first six correct entries to be picked out in a draw to be held after the competition closes on 2 September 1993.

To enter: Return the form below giving the five-letter 'Keyword'.

To discovery the 'Keyword', you first need to obtain the five numbers which are the answers to the following five questions about the STS-49 mission (see the STS-49 Mission Report on pp.270-273).:

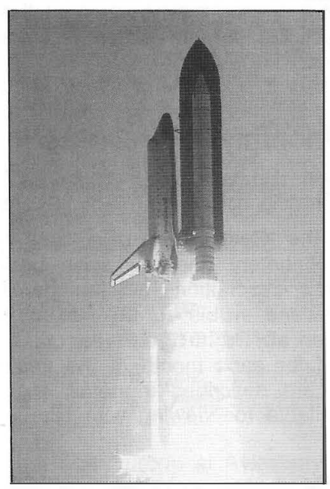
(1) How many months after delivery of Endeavour to the Kennedy Space Center did its launch take place?
(2) How many built-in holds were scheduled in the countdown?
(3) How many Mission Specialists were there in the crew?
(4) How many EVA operations were carried out during the mission?
(5) How many days did the mission last?

Secondly you need to relate each of the five numbers, in a simple way, to a letter of the alphabet, so obtaining five letters which when rearranged will provide the 'Keyword'.

The 'Keyword' is connected with the return of a Shuttle Orbiter to Earth.

Then complete this form and post it to arrive no later than first delivery on 2 September 1993.

Return to: The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.



STS-49 heads for orbit. *NASA*

Title/Name ....

Address ....

....

....

KEYWORD

BOOK NOTICES

These notices, compiled by L.J. Carter, are not intended to be reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

Full publication details are given for each book to enable copies to be ordered from a local bookseller, if desired. The address of each publisher also appears, for many items can now be ordered direct from them. If not, they will supply the address of a local agent who can handle matters.

The Millennial Project

Marshall T. Savage, Empyrean Publishing Ltd., 1616 Glenarm Place, Suite 101, Denver, Co 80202, USA, 1993, 514pp, $24.95 (Hardback), $18.95 (Paperback), $3.50 postage in USA.

This is a book that unashamedly takes an optimistic and positive look at human destiny and is specifically concerned with the sustained settlement of space.

The author provides a personal synthesis of the diverse speculations of "space visionaries", offering a blueprint for the next thousand years that starts with the growth of floating cities on the oceans ("...to feed the world and to learn the lessons of space colonisation...") and ends at the threshold of colonisation of the galaxy. Projects of intermediate scale take up the centre of the book, which considers efficient methods of getting into space; the construction of free-floating space colonies; the creation of miniature ecologies on the Moon; the terraforming of Mars and the transmutation of the substance of the Solar System into a Dyson Sphere.

The future is thus painted as a glorious golden age where life from our planet, husbanded by man, eventually spreads throughout the cosmos. The reader is assisted in his decision as to the realism of the author's version of this dream by tables of data, illustrations, a central section of colour plates and a substantial reference list.

The Monthly Sky Guide

I. Ridpath and W. Tirion, Cambridge University Press, The Edinburgh Building, Cambridge CB2 2RU, 1993, 63pp, £7.95.

This is the latest edition of a "first" book for any amateur stargazer. Planetary positions have been updated to 1997, while notes and descriptions aid the identification of those stars and constellations visible to the naked eye in the Northern hemisphere on any night of the year. Clear maps of the night sky are provided for each month of the years. Constellations of special interest are described in detail, together with other stellar objects suitable for viewing with binoculars or a small telescope.

To a Rocky Moon: A Geologist's History of Lunar Exploration

D.E. Wilhelms, The University of Arizona Press, 1230 N Park Avenue, Suite 102, Tucson, Az 85719-4140, USA, 1993, 477pp, $29.95.

The human exploration of the lunar surface which began in 1969 marked not only an unprecedented technological achievement but also the culmination of a great scientific effort to understand lunar geology. Videos and Memoirs of the Apollo astronauts have preserved the exploratory aspects of these missions but, now, a geologist who was an active participant in the lunar programme, sets out a detailed historical view of these events, starting from the pre-Apollo era and giving a previously untold scientific perspective.

A major responsibility of the scientific team, of which the author was a member, was to assemble an overall picture of the Moon's structure and history so as to recommend where, on the lunar surface, field-work should be conducted and samples taken. This book relates the site selection process in some detail and draws in many related events concerning mission operations and how these affected the development of the accompanying scientific programme.

Besides discussing all six lunar landings in detail, this book gives a behind-the-scenes story of the telescopic and spacecraft investigations conducted before, during and after the manned lunar landings.

Men and Woman of Space

D.B. Hawthorne, Univelt Inc., PO Box 28130, San Diego, California 92198, USA, 1992, 918pp, $90.

This monumental biographical work by a Fellow of the Society provides biographies not just of astronauts and cosmonauts but of *all* men and women who have been space-qualified. It features about 650 biographies in all, many in considerable detail, of space-qualified persons from every part of the world.

The volume is the culmination of many years of research and numberless interviews. The biographies are organised alphabetically but many tabulations are appended which makes for easy reference. A Foreword by Scott Crossfield, the first to fly the precursor of manned space vehicles, the X-15, is also included.

This is a unique reference work. We are not aware of any similar book which provides such a broad biographical coverage in such detail.

Members of the Society ordering copies from the Publisher are entitled to a 25% discount.

Gamma-Ray Astronomy

P.V. Ramana Murthy and A.W. Wolfendale, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1993, 259pp, £40.

The recent launch of NASA's Gamma-Ray Observatory has greatly increased interest in this relatively new branch of astronomy. This book, a fully updated edition of the author's earlier volume published in 1986, sets out the scientific background to what is becoming an increasingly-important field of research.

Gamma-ray astronomy gives us a view of the Universe through the most recently opened astronomical window and the emphasis here is firmly on the astronomy and astrophysics of the known sources of cosmic gamma-rays which lie outside our solar system. It starts with an introduction describing the mechanisms for the production and absorption of gamma-rays and follows with a discussion of gamma-ray astronomy of the interstellar medium, the galactic centre and various other discrete sources.

A further chapter treats gamma-ray bursts in considerable detail and the remainder of the book goes on to deal with medium energy and ultra-energy gamma-rays. The supernova SN 1987A continues to provide data of interest to gamma-ray astronomers, so results achieved so far are included in this edition.

Outpost on Apollo's Moon

E. Burgess, Columbia University Press, 562 West 113th Street, New York, NY 10025, USA, 1993, 274pp, $34.95.

An argument frequently put forward is that the exploration of the Moon and Mars will stultify other scientific areas or absorb funds which could be better spent on domestic concerns. The author of this work, a Fellow of the Society, refutes such arguments with a powerful affirmation of the need and importance of a wide-ranging space programme leading to the development of Lunar outposts and, ultimately to permanently-staffed Moon Bases.

He writes strongly, e.g. "Without continued expansion into space we will be sentencing our children to be stillborn in the womb of Earth".

His book begins with an examination of the scientific and philosophical rationales for space travel and gives an in-depth look

at the physical details of the Moon. Numerous tables, charts and illustrations support his analysis.

The success and failings of the various Apollo missions are then discussed. Using such programmes as a starting point, the author believes that Apollo hardware and experience can be developed to establish permanent human outposts on the Moon, parallelling what was done earlier in the Antarctic continent. He shows how the colonisation of the Moon could be valuable both to science and commerce and points to the manifold waste of resources already being committed by Governments and industries throughout the world. By comparison, investment in a space programme, including Lunar and Mars bases, is minimal.

Solid Rocket Propulsion Technology

A. Devenas, Pergamon Press Ltd., Headington Hill Hall, Oxford, OX3 0BW, 1993, 606pp, £125.

There are few books on solid propellants and their use in rocket propulsion and even fewer present a comprehensive review of the subject. This book is a translation, with slight adaptation, of a work originally published in French in 1989.

Restriction in the free flow of information has led to differing designs and methods in various countries. The French, for instance, have made intensive use of trimmed axisymmetric grain designs with high loading fractions, not developed elsewhere, and protected their design and production methods by secrecy for a long time. The USSR utilised a very specific composite formulation used in a family of missiles and with a binder based on a derivative of terpenic resin found only in the Ural forests of that country.

The text describes the current state of the art in solid rocket propulsion, with particular emphasis on solid propellants. It sets out the basic equations of rocket propulsion and the fundamental physics involved and details design principles and rules and coverage of the formulation and production processes of solid propellants and of the insulating materials used in rocket engines.

Care has to be exercised in the terminology adopted for propellants. This has still to be standardised so many equivalent names for the same propellant are found in the literature, or even in this book. Besides that, the French have developed their own specific terminology for composite and high-energy propellants.

ODYSSEY The Authorised Biography of Arthur C. Clarke

N. McAleer. Victor Gollancz Ltd., 14 Henrietta Street, London WC2E 8QJ, 1992, 430pp, £16.99.

Arthur Clarke has been a household name since 1968 when the film 2001: A Space Odyssey brought him international renown. Besides being one of the world's best science fiction writers, his has also been an influential voice in the development of satellite technology and global communications and, as one result, became a former President of the Society.

The present volume, published to mark his 75th birthday, also marks the first comprehensive account of his life.

When Arthur was born in Somerset in 1917, radio was in its infancy but his early experiments led him to become the prophet of satellite technology which was crowned with the publication of his 1945 article "Extra-Terrestrial Relays".

Arthur's science fiction output has achieved classic status and has resulted in him receiving all of science fiction's highest tributes. He has also received an Academy Award for the film 2001 and the honours for his work as a populariser and prophet include the Lindbergh Award in 1987 and the CBE in 1989.

The present book is based on a careful sifting of Arthur's works and extended interviews with friends, colleagues and family. The result is an account of his numerous travels and discussions with leading space personalities the world over. It is filled with stories and anecdotes and with "behind the scenes" accounts of discussions and experiences.

All in all, it provides a fascinating insight into a long and varied career of a Somerset farm boy who rose to international fame.

Chemical Principles Applied to Spacecraft Operations

R.E. Dueber and D.S. McKnight, Krieger Publishing Co., PO Box 9542, Melbourne, FL 32902-9542, USA, 1993, 200pp, $59.50.

The space environment poses challenges unlike any met with on Earth. Many disciplines must be blended if we are to understand both the environment itself and how spacecraft may be operated within it.

This book focuses on the chemistry of spacecraft operations and satellite-environment interactions. It starts with overviews of general chemistry and astrodynamics which provide a framework for later chapters. The make-up of the solar system is then dealt with, with emphasis on the near-Earth and planetary environments - so delineating the areas in which spacecraft must operate. All these set out the boundary conditions within which the chemical principles described in later chapters have to be applied.

Four subsequent chapters contain the "meat" of the text. They cover spacecraft materials, power and propulsion, thermal control and protection systems and investigate a wealth of matters e.g. corrosion, atomic oxygen attack, outgassing, condensation and radiation degradation on materials used in space. A section on LDEF describes the most current research into the analysis of spaceborne materials.

A final chapter considers important chemistry matters related more directly to manned space flight. The safe transportation of astronauts through the harsh space environment has always been a most demanding task, and one which will become even more challenging as the duration of manned missions increases.

At the Edge of Space: The X-15 Flight Programme

M.O. Thompson, Airlife Publishing Ltd., 101 Longden Road, Shrewsbury, Shropshire, SY3 9EB, 1993, 375pp, £18.95.

The author, an active pilot throughout the X-15 Programme, describes the story of one of the most successful research aircraft ever flown.

The X-15 Programme was initiated in the 1950s to test the survivability of rocket-powered aircraft at hypersonic speeds at the outermost limits of the Earth atmosphere. The nine phases of the Programme tested engine capabilities, altitude and speed capacity, pilotability and featured a number of experiments which were unrelated to the performance of the aircraft itself. In achieving hypersonic speeds, the X-15 yielded design and materials data which were essential for the subsequent Apollo and Space Shuttle Missions.

Isolated Pulsars

K.A. Van Riper, R. Epstein & C. Ho, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1993, 438pp, £40.

The study of extreme properties depicted by pulsars covers a wide range of physics which is spread over many disciplines. For example, pulsar magnetospheres involve plasma physics and electrodynamics while the structure and dynamics of their very dense interiors embrace nuclear and condensed matter physics.

This volume summarises and provides an up-to-date guide to recent advances in the theory and observation of solitary neutron stars. Observational highlights mentioned include results from the Compton Gamma Ray Observatory, the ROSAT X-Ray Satellite, the ASGAT and Whipple Observatory TeV experiments and the Hubble Space Telescope. There is also a section devoted to the experimental details of pulsar timing studies.

The well-illustrated theoretical contributions feature thermal and non-thermal emission mechanisms, interior dynamics following a glitch, the properties of dense matter, thermal evolution, the generation and development of magnetic fields, the rotation and oscillation of neutron stars and the interaction of the pulsar wind with surrounding nebula. The evolution of pulsars is also examined in the light of statistical studies of their galactic distribution.

The X-Ray Background

Eds. X. Barcons and A.C. Fabian, Cambridge University Press, The Edinburgh Building, Cambridge CB2 2RU, 1992, 310pp, £35.00 (ISBN 0-521-41651-5).

This book presents a review of the current observational knowledge and understanding of the cosmic X-ray background. Its spectrum, high galactic latitude isotropy on all angular scales and its source content, are reviewed in detail. The contribution of the Ginga, Rosat and BBXRT space missions, play a major role in the discussions of the most recent estimates of the contribution to the X-ray intensity of different classes of sources, mostly Active Galactic Nuclei and Clusters of Galaxies. The fraction of resolved background intensity approaches 50 per cent at soft energies, where QSOs dominate. At higher photon energies, where most of the energy density of the background resides, the fraction directly resolved is smaller. Models for the residual intensity are discussed with particular emphasis on spectral as well as isotropy constraints. The necessity of future space missions where the X-ray sky can be mapped with good angular resolution at energies from 0.3 to 10 keV is highlighted.

The Cambridge Guide to Astronomical Discovery

W. Liller, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1992, 257pp, £19.95.

This is a guide on how a keen amateur may make astronomical discoveries, using only modest equipment. Based on 20 contributions from both amateur and professional astronomers already famous for their discoveries, it describes the approaches to take in searching the skies for the unusual and unexpected.

There are all the kinds of objects that an amateur may hope to find as a result of systematic searching. Visual, photographic and electronic techniques are described and instructions given on how to report discoveries.

Many extensive Appendices embrace a wealth of further information of great value to a would-be discoverer.

Inside NASA: High Technology and Organizational Change in the US Space Program

H.E. McCurdy, The Johns Hopkins University Press, 701 West 40th Street, Suite 275, Baltimore, Maryland 21211, USA, 1993, 215pp, £27.50.

NASA started its Space Programme in October 1958 with the launch of the 84 lb Pioneer 1 Space Probe. Scarcely a decade later, by July 1969, it had amazed the world by landing the first men on the Moon. Gradually, however, the euphoria vanished, to be replaced in recent years by severe criticism and, as one result, NASA now appears to have lost some of its vigour and creativity.

This book sets out to explain the course of events, i.e. an Agency once praised for its planetary probes and lunar expeditions became subsequently associated with the Challenger disaster and a series of other malfunctions. Using archival evidence and interviews with some of the officials most concerned, the author begins by setting out the norms, the practices that guided NASA's early successes.

At first the Agency was dominated by the strong technical culture and enthusiasm which it had inherited from the research and development organisation from which it had been formed. Its technical culture which led to the lunar expeditions was based on and linked to a structure associated with the USAF Ballistic Missile Programme. However, in course of time, gradual changes led to increased bureaucracy in all Governmental Agencies as a whole, which affected NASA, too, in eroding its original cultural and technical strength.

The author concludes that a resulting effect of all modern government now is that the performance of high-technology agencies like NASA has an inherent tendency to decline. To this extent, the book is really a study in both organisational and bureaucratic "ageing".

SOCIETY MEETINGS DIARY

22 September 1993 10 am - 4.30 pm

European Rocketry in the 1930's

As part of the Society's Anniversary Year the History Working Group is holding a Symposium on European Rocketry in the 30's. Contributions have been invited from Germany, France, Russia and the UK. The 30's is seen as a particularly interesting decade in that much theoretical and practical work was undertaken that laid solid foundations for later projects.

Whilst much publicity has surrounded the experimental and theoretical work carried out in Germany an enormous amount was also carried out elsewhere, particularly in Russia. Much of this story has yet to be told.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Advance Registration is necessary.

Registration: Forms are available from the Executive Secretary. Please enclose a sae.

15 - 17 October 1993

SPACE '93

This two-day meeting commemorates the Society's Diamond Jubilee, 1933 - 1993. Please send to BIS HQ for details.

16 - 22 October 1993

44th International Astronautical Congress

The 44th International Astronautical Congress will be held in Graz, Austria, from October 16 - 22, 1993. Details of the Programme, Registration Forms, etc. are available from BIS HQ.

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.

It may occasionally happen that, for reasons outside its control, the Society has to change the date or topic of a meeting. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always recheck the scheduled meetings in the latest issue.

1 September 1993 7 pm - 8.30 pm

SOHO - A Unique ESA/NASA Mission to Survey the Sun

D.M. Simpson, Matra Marconi

The Solar Heliospheric Observatory (SOHO) is an ESA mission which forms part of the Solar Terrestrial Science programme and should contribute towards the International Solar Terrestrial Physics programme. As such it is a cornerstone of the ESA Horizon 2000 plan.

SOHO will make observations of the solar surface, corona and solar wind as well as detect any oscillations of the solar surface. Such observations will be carried out continuously from an orbital location between the Earth and the Sun, circling the L1 libration point.

Matra Marconi Space are the prime contractor for SOHO which is planned to be launched using an ATLAS 2AS.

The speaker will outline the mission, provide technical background on the design and give a prognosis of the likely results from this highly ambitious, measurement laden, mission.

6 October 1993 7 pm - 8.30 pm

Microsatellites on Micro-budgets

Prof. M. N. Sweeting

The prohibitively high cost of space projects has effectively restricted first-hand access to space to a handful of nations and international agencies. Spacecraft have grown ever larger and more complex and are also taking longer time-scales from concept to orbital operation. Advances in VLSI micro-electronics have catalysed a new species of small, low-cost yet sophisticated and highly capable 'microsatellites' - complementing, and sometimes providing an alternative to, high-cost traditional satellites.

The lecture describes the University of Surrey UoSAT microsatellite programme which reviews the key technologies, management techniques and potential applications of small satellites.

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The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. The Library will also be open on Saturdays between 10.00 am and 1.30 pm on the following dates:

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23 October 20 November
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Spaceflight

The International Magazine of Space and Astronautics

Mars Now !!

"Mars Observer" the Polar Orbiting Probe

• Stanford Study Mission to Mars •
• The New Human Migration: Colonising Mars •
• Bringing Worlds to Life •

STS-57
Shuttle Mission

'Name the Sats'
Competition
Prizes to be Won!!

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by
Keith A. McNeill

ISSN 0038-6340
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Apollo 8: Go For TLI

This Saturn V flight was man's first journey around the Moon and forerunner of the Apollo lunar-landing flights. The three-man crew (Borman, Lovell and Anders) set course for the Moon, passed behind it and transferred to a lunar orbit, circling the Moon ten times in 20 hours. Their many still photographs and much cine film helped to decide on landing sites for later missions. The final TV transmission took place while 97,000 miles from Earth. *22 mins*

Apollo 9: Three to Make Ready

Building on the successful flight of Apollo 8, a lunar module was tested in space, as was the life support system of the space suit. Two of the three-man crew (McDivitt, Scott and Schweickart), transferred to the Lunar Module, moved 100 miles away from the Command Module and then returned to rendezvous with it. The two men then transferred back to the Command Module and the Lunar Module was jettisoned. *17 mins*

Apollo 10: To Sort out the Unknowns

Lift-off to a trans-lunar orbit by Stafford, Young and Cernon, with views of Earth and system checks *en route*. There was loss of communications signal while passing behind the Moon as the craft transferred to lunar orbit. Signal acquisition returned when the spacecraft reappeared, with TV pictures showing the Lunar Excursion Module (LEM) undocked from the Command Module and descending to within 50,000 feet of the lunar surface. Direct communications between Control and LEM failed so access was made *via* the CM. LEM subsequently rendezvoused with the CM, the crew transferred again and LEM was jettisoned. *26 mins*

STS-49 Mission Highlights

The details of this flight by the Shuttle Endeavour, 7-16 May, 1992, are well covered, e.g. the preliminaries of suiting-up, the White Room, entry to orbiter, removal of gantry, count-down, engines start, lift-off, and detailed operations during the flight. A principal aim was to retrieve the Intelsat VI satellite which had previously failed to reach synchronous orbit. Though more difficult than expected, it was achieved and sent on its way. A second aim was to practice basic space station assembly work by Extra-Vehicular Activity (EVA). This was also very successful. The video concludes with an interesting press interview with the crew. *1hr 50 mins*

Mission of Apollo Soyuz

In July 1975 spacecraft from the Soviet Union and the United States blasted off on an historic mission. Two days after blasting off Apollo and Soyuz docked high above the Atlantic Ocean. This NASA film covers the scientific and technological achievements of the mission and stresses the spirit of cooperation and friendship. *28.5 mins*

Time of Apollo

In 1961, President John F. Kennedy set forth the task... "This nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth". This film is a tribute to the historical accomplishments of the Apollo programme. *29 mins*

Skylab: The First 40 Days

Records the launch of the unmanned Skylab 1, the major problems that followed and the repair during the manned Skylab 2 mission. Includes on-board sequences of daily work routines and some of the experiments. *22.5 mins*

Skylab: The Second Manned Mission

Covers the Skylab launch activities and docking with the orbital workshop. Includes observations of student experiments, crew medical experiments, exercise routines and the activation of the Earth Resources Experiments Package. *36.5 mins*

The World Was There

This NASA film, using original footage from the sixties, shows how the news media of the World covered the manned space launches of NASA's project Mercury. *27.5 mins*

STS-49 Post-Flight Crew Press Conference

Shuttle flight STS-49 proved to be the most dramatic mission in the 11-year history of the programme. Endeavour, on its maiden flight, had to chase the Intelsat-6 satellite three times. The first two attempts to capture the satellite ended in failure. On the third and, finally successful attempt, it took a record-braking three spacewalkers to grab the slowly spinning satellite. In this NASA production the STS-49 crew describe their daring mission. *22 mins*

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Spaceflight

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Front Cover: Artist's illustration of Mars Observer in orbit around the Red Planet with its solar panels drawing energy from the Sun. The spacecraft's orbit is sun-synchronous; Mars Observer will pass over the planet's equator at the same local time during each orbit - about 2 pm on the day side and about 2 am on the night side.
General Electric Astro-Space Division, Princeton, New Jersey

Mars Now !!

With the arrival of Mars Observer at the planet Mars on 24 August, NASA will be continuing a programme of exploration that started with Mariner IV in 1964. The last US spacecraft to visit Mars was Viking 2 in 1976. In the intervening years the technology of planetary exploration has moved on and a new phase of Mars explortion has now started.

In this issue, present plans for exploring the planet and ideas for its future manned exploration and colonisation are put forward:

Titan III / TOS Data

BOOSTERS	
Size:	27.6 m long by 3.1 m diameter
Thrust:	6200 kN / motor
Propellant:	UTP-30001B (solid)
FIRST STAGE	
Size:	78.6 m long by 3.0 m diameter
Thrust:	2437 kN
Propellant:	Aerozine 50, nitrogen tetroxide
SECOND STAGE	
Size:	10 m long by 3.0 m diameter
Thrust:	467 kN
Propellant:	Aerozine 50, nitrogen tetroxide
TOS	
Size:	10 m long by 3.3 m diameter
Thrust:	270 kN (max)
Propellant:	Hydroxyl Terminated Poly-Butadiene (solid)

Mars Observer

On 24 September 1992 at 1.05 a.m. local time the Mars Observer spacecraft was successfully launched from Cape Canaveral and is now close to completing its 11 month journey to Mars. This is the first American mission to Mars since the two Viking spacecraft were launched in 1975. Although the mission will not be as spectacular as Viking - there will be no landing and no search for life - The Mars Observer will start the process of mature science, filling in the detail of the broad picture of Mars we already have from earlier missions.

BY MARK HEMPSELL
University of Bristol

Dr Wesley Huntress, Director of NASA's Solar System Exploration Division explains. "Mars Observer will examine Mars much like Earth satellites now map our weather and resources. It will give us a vast amount of geological and atmospheric information covering a full Martian year. At last we will know what Mars is actually like in all seasons, from the ground up, and pole to pole."

So the "Mars Observer" is well named as it will perform the same function on Mars as Earth Observation spacecraft currently do on Earth. This similarity of mission is reflected in all aspects of the programme from the design of the spacecraft, the selection of the experiments, and the choice of operational orbit and mission profile.

Launch System

Mars Observer was launched by a Titan III booster and a TOS (Transfer Orbit Stage) upper stage.

The Titan III was originally developed by the USAF in the 1960's from the Titan II as a launcher for the X-20 Dynasoar and later the MOL (Manned Orbiting Laboratory). It is now the largest launch system in the USA inventory and has a distinguished record as a launcher of planetary probes having successfully sent both the Viking and Voyager spacecraft on their way to the planets.

The Titan III that was used came from the Martin Marietta commercial Titan programme which includes European members in its contractor team. Dornier GmbH of Germany and Contraves AG of Switzerland make the payload fairing.

After lift-off from Pad 40 at Cape Canaveral the Titan placed Mars Observer and its TOS upper stage into a low Earth orbit. The total mass in orbit was a little under 13.5 tonnes, well within the capability of the Titan.

The Mars Observer launch was the maiden flight of the TOS. This addition to the USA launch system inventory has an unusual history in that it was developed on a commercial basis by Orbital Sciences Corporation, rather than as a result of a request by NASA itself. It was originally intended as a large upper stage for the Space Shuttle, but since the redirection of the Shuttle programme after the loss of Challenger it also has found a role with Titan III. It uses a United Technologies' ORBUS-21 solid propellant rocket motor which was originally developed as the first stage of the IUS (Inertial Upper Stage). For the Mars Observer mission the motor was loaded with almost 10 tonnes of Hydroxyl Terminated Poly-Butadiene (HTPB) propellant.

TOS is three-axis stabilised with a Honeywell laser inertial navigation system controlling 12 hydrazine thrusters for stabilisation in roll, pitch and yaw. Batteries and an S-Band telemetry system complete the avionics suite.

Fifteen minutes after lift-off the TOS separated from the Titan. it then waited in low Earth for 20 minutes before performing a 150 second burn which put the Mars Observer into an escape orbit towards Mars.

As a tribute to the past NASA administrator who died shortly before launch the TOS had a plaque bearing the legend "USS Thomas O. Paine".

The Mission

Once the spacecraft had separated from the launch system it reconfigured itself for the 11 month cruise phase of the mission. This involved the deployment of four of its six solar power panels, deployment of the high gain dish antenna and the partial deployment of the two experiment booms. During the cruise phase the only planned major activity concerned four mid course corrections and spacecraft checkout. in addition minor glitches had kept the ground team busy as ***Spaceflight's*** Space Probe Diary has recorded in its regular reports on the spacecraft.

On reaching Mars, Mars Observer fires its main propulsion to place it into a highly elliptical capture orbit. Over the next four months a series of seven manoeuvres move the spacecraft into its final mapping orbit. During this mis-

- Arriving For Work

sion phase only limited science can be accomplished as the spacecraft is still in its cruise configuration.

Mars Observer should reach its final operational orbit (called the mapping orbit) in mid January 1994. When it has arrived the solar power panels and the instrument booms will complete their deployment and the main scientific programme can begin. The experiments, data handling and power systems are all sized to continuously observe the planet with all the instruments. Only the MOC camera will be restricted to daylight use for obvious reasons.

Like the payload the final operational orbit is a Martian version of the orbits used by Earth Observation satellites. It is a circular orbit at 378 km altitude. It is a near polar orbit and therefore virtually the whole planet will be mapped pole to pole. The actual inclination of 93 degrees is sun-synchronous; that is perturbations will move the orbital plane around slightly each day by the same angle as the Sun moves due to the motion of Mars along its orbit. So throughout the mission the Mars Observer will always fly over the daylight side during the early afternoon at about 2 o'clock, and therefore about 2 o'clock in morning on the night side. As with Earth observations it is important that observations of a point on Mars are always made at the same time of day so variations can be attributed to seasonal effects not to the time of day.

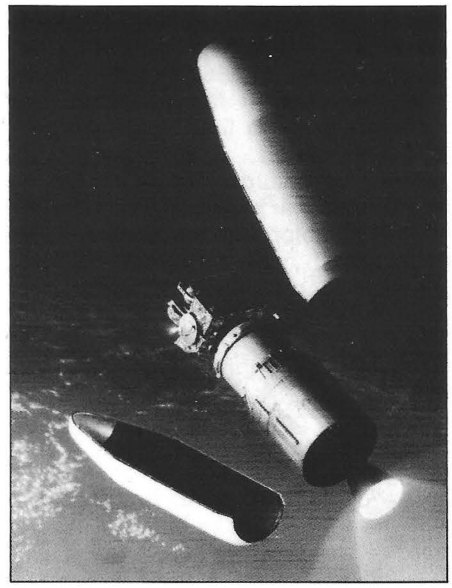
The operational orbit should be reached at the start of the Martian Autumn in the northern hemisphere and Spring in the southern hemisphere (see the Mission Timeline p.293). Within a few months the dust storm season should begin which can last for much of the northern winter. Mars Observer should get data on these events and continue its monitoring of the entire planet for a least 686 days which is a complete Martian year finishing as the next Autumn starts in November 1995. The official end of the mission is currently planned for January 1996.

Mars Observer should return about 120 megabytes of data a day so by the planned end of the mission a total of 80 to 90 gigabytes will have been received. This is more than all previous planetary probes (excluding Magellan) put together.

Propellant and the batteries are the two items that are expected to determine the lifetime of the spacecraft but if there is enough propellant and the batteries are in good condition then the mission could continue into a second Martian year. If the planned Russian Mars 94 mission is successful then Mars Observer will support this both by providing complimentary data and also acting as an additional relay of data from the surface experiments using the Mars Balloon Relay (MBR) as discussed below.

Mars Observer Spacecraft

The Mars Observer spacecraft was built by GE-Astro in Princeton, New Jersey. The design philosophy was to maximise the use of components that were already developed for Earth orbiting missions. The company has a long history of building both communications and Earth Observation satellites and Mars Observer drew on both. The basic structure and thermal subsystem were based on the company's SATCOM K and the electronics were derived from TIROS N and the Defense Meteorological Satellite. The

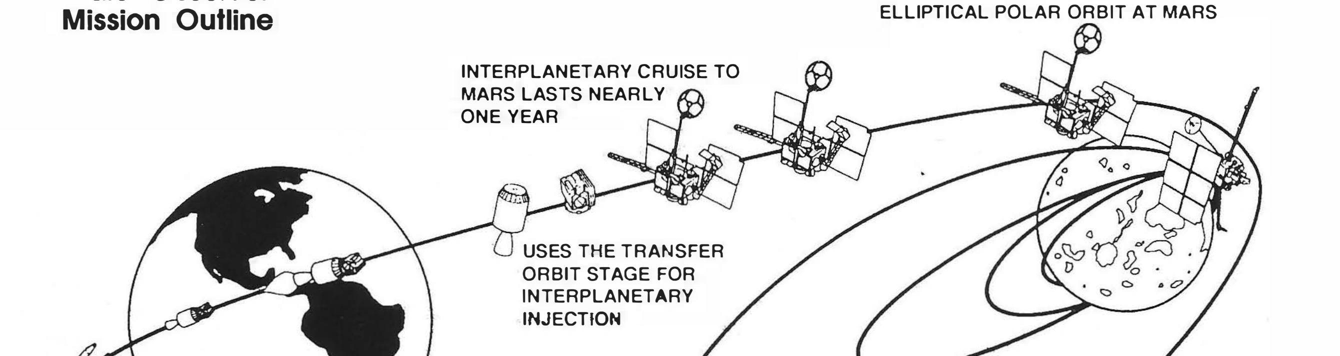


The payload fairing is jettisoned in Earth orbit and the Mars Observer spacecraft, attached to the Transfer Orbit Stage (TOS), is readied for deployment into its trajectory to Mars. An artist's illustration. *NASA*

spacecraft has a design life of 3 years which is intended to cover the flight to Mars and a complete Martian year of observations.

Mars Observer is a three-axis stabilised spacecraft although it does employ a slow spin during the outward flight to keep temperatures even. It determines its attitude using a combination of a star sensor and horizon sensors. Obviously during the journey to Mars the horizon sensors cannot be used as there is no planetary horizon to see so the spacecraft relies solely on the star sensor. This gave some trouble during the cruise mission which was corrected by software updates to the spacecraft computer. Once in Martian orbit the horizon sensors which are based on a design for Earth orbiting spacecraft are the primary means of determining attitude, with the star sensor as a backup. The

Mars Observer Mission Outline



JPL

attitude is controlled by reaction wheels which can point the spacecraft to an accuracy of about half a degree.

The spacecraft is unusual for a planetary probe in that it has two propulsion systems. A monopropellant system for attitude control functions uses hydrazine propellant and a second larger bipropellant system uses monomethyl hydrazine and nitrogen tetroxide to provide the primary propulsion for orbital manoeuvres. Mars Observer has a total of 24 rocket engines ranging in thrust from 490 N to 0.9 N.

Electrical power is provided by a large six panel solar array. The strength of the sunlight at Mars is only a little over 40% that at Earth so the array needs to be more than double the size of an Earth satellite array. In Martian sunlight the array produces 1130 watts which are fed to the spacecraft electrical equipment via a voltage regulated power bus. There is a 40 minute eclipse in each 118 minute orbit and at this time two nickel cadmium batteries, each rated at 42 amp-hr, power the spacecraft.

Downlink communications use a 44 watt transmitter fed through a 1.45 m diameter dish antenna. This can return 83,500 bits of data a second when the Earth is visible. This is used to playback the contents of the tape recorders on which the scientific and engineering data are recorded. In addition to the recorded data some real time images can be added every 3 days from the Mars Observer Camera.

Mars Observer Technical Data

Body Dimensions:	Length 1.6m, Width 2.2m, Height 1.1m.
Mass at launch:	2573 kg of which 156 kg is payload and 1364 kg is propellant.
Downlink Data:	Maximum rate 85.3 kbits/sec through 1.45m diameter antenna.
Pointing:	Control to 0.57°: measure to 0.17°.
Array Power:	1130 watts from single 6 panel array, each panel 1.8m x 2.2m.

The Experiments

Mars Observer has eight science instruments on board. These are designed to provide a thorough measure-

What is Pressure Modulated Radiometry ?

The use of gas pressure modulation was pioneered by the University of Oxford group as a very powerful tool for measuring the detail of infra-red emission lines in the spectrum from a planet's atmosphere. Their past projects include SAMS (Stratospheric and Mesospheric Sounder) flown on Nimbus 7, and ISAMS (Improved Stratospheric and Mesospheric Sounder) flown on UARS (Upper Atmosphere Research Satellite), both of which looked at the Earth's atmosphere, and VORTEX (Venus Orbiter Radiometric Temperature Sounding Experiment) flown on Pioneer Venus.

The technique allows investigation of the structure of the atmosphere, its composition, temperature, pressure and other factors like aerosol content. Measuring the infra-red spectrum is inherently difficult because of the background noise including that caused by the emissions of the spectrometer itself. Pressure modulation is a method of detecting the weak signal from a single gas in the atmosphere amongst this noise and amongst signals from other gases so that composition and temperature information can be extracted.

The infra-red radiation is collected looking at the planet (in this case Mars) with a moving mirror which scans the limb - thus looking from the top of the atmosphere to the surface. This mirror focuses the infra-red radiation on to a rotating mechanical chopper that switches the signal from the planet to deep space a thousand times a second.

By examining the eventual electrical signal at this frequency a comparison is made between the signal from the planet and that from deep space (at only 3 degrees above absolute zero) and this allows the absolute intensity of the incoming radiation to be established.

To remove unwanted regions of the spectrum an interference filter allows only a narrow band of radiation frequencies to reach the detector, but even within this narrow band there can be several hundred emission lines from the gas under examination as well as many more lines from other gases.

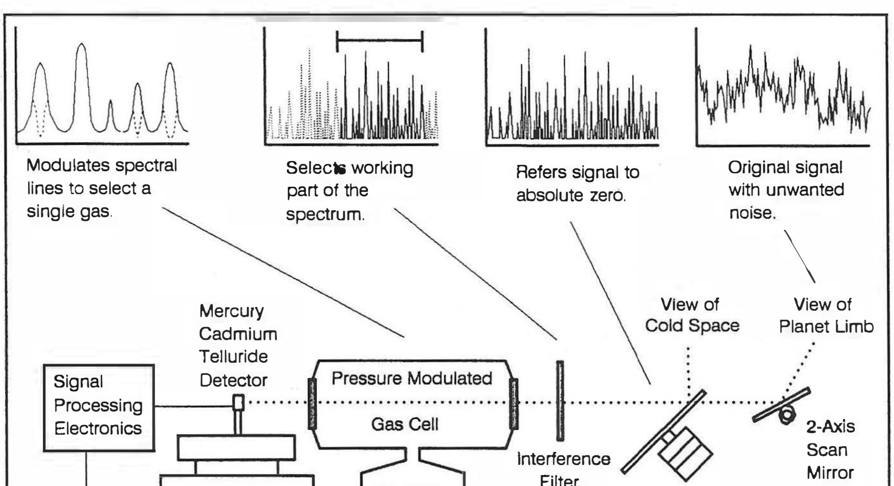
The signal is then passed through a gas chamber which contains the gas under examination. The gas in the chamber will absorb radiation at the same frequencies as the emission lines in the original signal of the same gas. The amount of absorption in terms of both the depth and the width of the line will depend upon the temperature and pressure in the chamber and this is varied 30 times a second (30 Hertz) by a balanced pair of pistons. This is the "Pressure Modulation" after which the system is named.

The gas chamber allows examination of only one gas of the many gases those spectral lines are in the spectrum. By looking at the final signal at the 30 Hertz frequency the way that the varying absorption lines are superimposed on the original emission lines can be established and hence the strength of the original lines of the subject gas can be determined. The absolute intensity of the emitted radiation is related to the temperature and partial pressure of the original gas in the atmosphere.

To enable optimisation of the instrument to examine the atmospheric layers of interest the mean pressure in the chamber can be altered. Typically the change in gas pressure is from a few millibars to over 10 millibars.

The radiation is finally focused on an infra-red detector made of mercury cadmium telluride. This converts the infra-red radiation to an electrical signal. To prevent this signal being lost in the thermal noise of the detector it is cooled to below 90K (183 °C below freezing) by a passive radiative cooler.

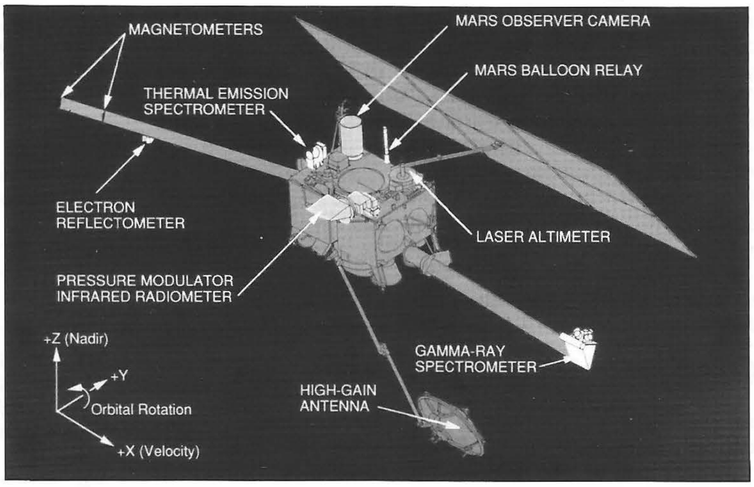
The Mars Observer PMIRR instrument has two gas chambers and detectors so that it can look at carbon dioxide and water vapour. Measurements on these two gases will enable the scientific objectives to be met and hopefully gain a more complete understanding of the Martian atmosphere.



ment of all aspects of Mars and its local environment. In many respects the payload on Mars Observer is very similar to the payload complement on a typical Earth Observation satellite.

The Mars Observer Camera (MOC) will provide photographs of Mars to a higher resolution than any previous spacecraft. It can take pictures in three resolutions, the lowest resolution (7.5 km per pixel) will be used for "weather mapping", the camera can also be switched to a medium resolution (240 m per pixel) for general mapping work and to monitor changes that take place over the year. A separate set of optics allows very high resolution pictures to be taken with 1.4 m per pixel accuracy. This high resolution mode will be used selectively on areas of special interest.

There are two instruments which are intended to examine the geology of Mars. These are the Gamma Ray Spectrometer (GRS) and the Thermal Emission Spectrometer (TES). The GRS measures the gamma ray emission from the surface enabling the surface elemental composition to be determined and also water and carbon dioxide ice to be detected. The TES uses a spectrometer to analyse the infrared radiation which allows the surface mineral content to be established. Russian and German scientists are included in the investigation teams for these instruments.



Mars Observer Mapping Configuration. With its science booms fully extended and the high-gain antenna in place to relay data back to Earth, Mars Observer will begin its mapping mission, rotating once per orbit to keep the science instruments pointed at the planet. *NASA*

The atmosphere is investigated by two experimental techniques one of which has no actual instrument, but uses alterations to the radio downlink signal when it passes through the atmosphere to make measurements of structure, pressure and temperature of the atmosphere. The radio science investigation will give the best information on the way that the Martian atmosphere varies with height.

There is no better example of the commonality with Earth Observation spacecraft instrumentation than the science instrument dedicated to atmosphere measurements called the Pressure Modulator Infrared Radiometer (PMIRR). This measures infrared radiation from the atmosphere looking at the limb and is based on a British experimental technique that has already been used to explore the atmospheres of Earth and Venus. It will measure pressure, temperature, water vapour and dust content with a vertical resolution of 5 km. Scientists from Oxford University are collaborating with American scientists on this Instrument.

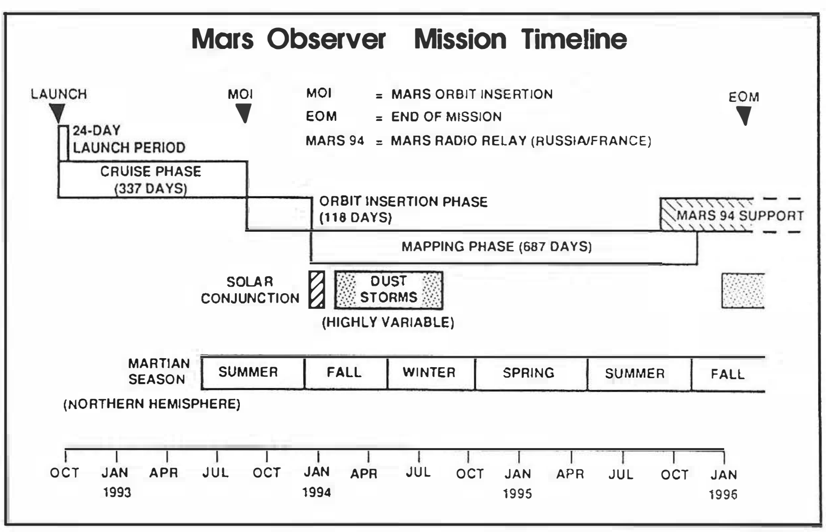
The gravity field around Mars will be explored by detailed measurement of the Mars Observer's orbit over time. The spacecraft altitude will be measured to an accuracy of a few meters by the Mars Observer Laser Altimeter (MOLA). This data will be supplemented by tracking using Doppler shifts in the radio downlink. It is hoped that detailed variations in the gravitational field will be linked to surface topography providing a better understanding of the large scale features of the planet.

Mars Observer also has a Magnetometer and Electron Reflectometer. This will be searching for a Martian magnetic field, although earlier spacecraft have failed to detect one. This instrument will see if there is a very weak field and will also search for magnetic fields in the surface rocks that may indicate that an earlier field existed. The experiment will also ex-

amine the interaction of the solar wind with the Martian upper atmosphere. French, German and Russian scientists are in the investigation team for this experiment.

The final payload package does not actually make any scientific measurements but rather is an encouraging example of international collaboration. Called the Mars Balloon Relay (MBR) It was supplied by the French space agency (CNES) and is intended to support the Mars 94 mission that will be launched by the Russians in October 1994. This spacecraft will deploy penetrators and small landers at several locations about the Martian surface. The MBR will pick up the radio signals from these landers and relay them back to Earth so that more data is returned than with only the Mars 94 orbiter acting as a relay.

If Mars Observer can extend its mission and is still operating in 1997 when the planned Russian Mars 96 spacecraft arrives, the MBR will be used to relay data from a French balloon which will be deployed on the Martian atmosphere on that mission.



Conclusion

Mars Observer represents an exciting new phase of Martian exploration. It has a new level of instrument sophistication aimed at exploring the dynamics of the planet. This will not only increase our understanding of Mars, but by providing a different example measured with virtually the same instruments as Earth Observation satellites it will help us achieve a much better understanding of our own planet.

UK Experiment Onboard Mars Observer

The University of Oxford is playing a crucial role in one of the experiments on Mars Observer. *Spaceflight* asked Prof F.W. Taylor, Head of Atmospheric Oceanic and Planetary Physics about the experiment and the importance of its results. He explained as follows.

The research programme of the Department of Atmospheric Physics is involved with experiments to study the physical processes in planetary atmospheres which control their global scale behaviour. Although our emphasis is generally on understanding the terrestrial environment and the physics underlying climatic change we have had major involvement in Pioneer Venus and Galileo Jupiter Orbiter. Our participation in the Mars Observer mission continues this tradition.

The study of the same physics at work in unusual planetary environments provides feedback and stimulation to our terrestrial work as well as being important investigative science in its own right. In this spirit we submitted a joint proposal with the Jet Propulsion Laboratory to NASA when the Mars Observer mission was announced for an instrument called the Pressure Modulator Infra-red Radiometer (PMIRR for short).

Here at Oxford our excitement stems from the fact that for the first time a dedicated atmospheric remote sounding instrument is in the payload of a Mars mission and it is partly built by us. Part of its scientific importance is because it is very similar to instruments we have already flown in polar orbits around the Earth and Venus and we are very keen to compare in detail the three Earth-like planets. Our experience with Pioneer Venus taught us that Venus does not behave at all like a scaled version of the Earth, and this tells us that our understanding of the Earth (as expressed in climate models, for example) is more empirical and less fundamental than we thought it was or would wish it to be.

Basically, we just want to look at how Mars' atmosphere behaves. What happens when a third of the atmosphere freezes out on the polar caps in the winter? How do the global dust storms blow up? What do the Martian analogues of large terrestrial weather systems look like? By measuring humidity as the temperature changes with season, can we infer where the reservoirs of frozen water lie under the surface? How much heat/water/dust is moved around during the seasonal cycle?

To help answer these questions the PMIRR has as its objectives to:

- map the three dimensional and time varying thermal structure of the atmosphere from the surface to 80 km altitude
- map the atmospheric dust loading and its global, vertical and temporal variations
- map the seasonal and spatial variation of the vertical distribution of atmospheric water vapour to an altitude of at least 35 km
- identify and map atmospheric condensates and their spatial and temporal variation
- map the seasonal and spatial variability of atmospheric pressure
- monitor the polar radiative balance.

To achieve these objectives the PMIRR measures the intensity of thermally-emitted infrared radiation from the Martian atmosphere limb (i.e. viewing in a direction tangential to the surface) and discriminates between different species such as carbon dioxide, water vapour and dust using the high resolution spectroscope technique of pressure modulated radiometry. It also measures in broad spectral bands for energy budget studies.

Data analysis will begin in November 1993 two months after Mars Observer arrives at the planet. It will take at least one Martian year (about two Earth years) of data acquisition, followed by several more years of detailed analysis, to paint the first reasonably complete picture of the contemporary Martian climate.

Mark Hempsell

Preparing for the Mars-94 Mission

The Russian Academy of Sciences' Space Research Institute is now busy preparing for its next mission to the Red Planet, due to begin in October 1994. The Mars-94 automatic probe is being constructed at the famous Moscow-based Lavochkin R&D association which has constructed all Soviet interplanetary probes to have been sent to the Moon, Mars and Venus. Yuri Milov, deputy general manager of the Russian Space Agency, says he is sure that the project will be implemented on time and in accordance with the proposed research programme. "We are going to accomplish it despite major financial problems".

BY Y. TELEGIN
RIA - Novosti (London)

Together with their numerous foreign colleagues, Moscow researchers Drs Vasili Moroz and Leonid Xanfomaliti are to equip the Mars-94 probe with an impressive array of scientific instruments. The spacecraft will be carrying two small weather stations that are expected to transmit specific weather data from the planet's surface. Apart from that, it will feature two 40-kg mini-probes (length, 1.5m; diameter, 12cm), which are to dig into the Martian soil, subsequently studying its geological composition and mechanical properties.

The descent modules are to relay all information back to Earth via the main orbital module which will itself be conducting remote surveys of the planetary surface. Part of all this information will be beamed back via the US Mars Observer satellite replete with a French-made transmitter.

French researchers are taking an active part in pre-flight preparations. Among other things, they are building a special balloon for the next Russian interplanetary probe due to reach Mars in 1996. This balloon will carry an instrument-packed unit over the Martian surface which will register ambient-air temperature, pressure, humidity, dust content, wind speed, as well the physicochemical and electromagnetic properties of various ores, including their frozen-water content. An airborne TV camera will pinpoint even the smallest details of the planet's surface (up to 10cm diameter).

The small, Russian-made Marsokhod (Mars Roving Vehicle) will be sent to Mars together with the balloon proper. It has already been tested in the Mohave Desert in California last May. The tests were attended by its Russian developers, experts from the Planetary Society, two Hungarians who had created the Marsokhod's processors and four French mobile robot-navigation experts from Toulouse.

The 75-kg Marsokhod will parachute to Mars. The soft-landing system, which includes several inflatable shock absorbers, was first successfully tested aboard Luna-type automatic probes in 1966. The rover has six wide drive wheels measuring 350mm in diameter. These coupled wheels are so wide that they virtually touch each other and therefore the vehicle does not scrape the ground as it goes. It can both "walk" and "roll" along the planet's surface and, consequently, can negotiate sand and other berms.

To handle the problem of the long travel time of radio signals researchers have come up with autonomous and semi-autonomous driving modes for this vehicle. The main driving parameters (overall direction, location of stop-overs and their duration) will be relayed from Earth via radio. For its part, the Marsohkod is expected to detect and bypass various obstacles on its own.

One of the Americans who had taken part in the tests of the Mars rover spoke highly of it. The Marsokhod's capabilities were demonstrated at a news conference in Los Angeles. A huge trailer tire was laying in the centre of the pavilion and the remote-controlled vehicle was supposed to bump into this obstacle, eventually passing it by. However, somebody failed to push the radio button on time and the rover fell into it. After 'assessing' the situation, the Marsokhod climbed out, with everyone shouting wildly.

The Russian Federation's State Space Programme envisages several more unmanned flights to Phobos and Mars during 1998-2001. These missions are to bring soil samples back to Earth. All research will be conducted within the framework of an international cooperative arrangement involving researchers and companies from over 20 states in Europe and the Americas.

Mission to Mars

Stanford Study Advocates Direct Route to Mars

A study, led by Bruce Lusignan of the Department of Electrical Engineering, Stanford University concludes that the first humans could land on Mars by 2010 and that a permanent base could be set up within four years.

BY RAYMOND HARDIE *
Stanford, California, USA

An International Project

In June 1991, NASA coincidentally had produced its own report on a Mission to Mars study, chaired by Tom Stafford, an Apollo astronaut who flew missions in 1969 and 1975. A few weeks later, Lusignan presented the results of the Stanford study at a press conference on Capitol Hill in Washington, D. C. The genius of Stanford's plan is in its simplicity. Its essence: Make the Mission to Mars project international, not national, in scope.

The Stanford study's conclusion was based on two realities that were crystallizing in the aftermath of the Cold War. First, the resources available from individual nations for space exploration were shrinking and, second, international resources from former enemies were now available. These factors opened the way to construct a truly international expedition to colonize Mars.

From its first year, the Stanford study made the idea of international cooperation a central part of its research. In 1991, Lusignan invited five Russian scientists to join a team of four Stanford professors and 25 Stanford graduate engineers in the manned Mission to Mars study. The Russian members of that Stanford study were Sergei Stoiko, one of the top manned-spacecraft designers from the Energiya Corporation; Eugene Narimanav and Anatolii Evitch of the Research Institute of Machine Building; and Vladimir Kotin and Yuri Ivschenko of the Lavochkin Association-Babakin Center.

The Stanford study was not the first to advocate the international possibilities of a Mars mission but it was one of the first to practically evaluate such Russian technology as the Energiya heavy-lift launch vehicle.

Bypass the Moon and Freedom Space Station

In advocating an international mission, the Stanford study was putting forward the most cost-effective mission available. With the bottom line always in mind, the study also dismissed the need for an incremental approach to Mars. It concluded that if the United States made a landing on Mars a goal there was no need to first construct a space station and then go on to build a base on the Moon, both of which were advocated in the NASA study. The Stanford study concluded that the best route to Mars is a direct one.

"It might add 100 percent [to the cost] to establish a Moon base," Lusignan says. "Mars has an atmosphere and you use that to help you slow down when you get there. You don't have that on the Moon. So the actual fuel needed to put equipment on the surface of the Moon is almost the same as it is to put it on Mars".

Lusignan also sees the mixing of a Moon mission and a Mars mission as akin to mixing apples and oranges. "The technologies that you would use to go to the Moon are not very similar to those that you would use for Mars," Lusignan says. "The space suit has to be different. The habitats have to be very different. The landing system has to be different. So you are not going to benefit very much from having gone to the Moon. The question is, since you are not going to benefit from it, in which order should you do it or should you do the Moon at all?

In like manner, the Stanford study dismisses the necessity for a space station as part of a cost-conscious Mars mission. Lew Franklin, a former vice president in the space defense section of TRW, who is now a visiting scholar at the Center for International Security and Arms Control at Stanford, is also sceptical about the need for a space station before a manned Mars mission. "I think the space station Freedom contributes more to current jobs than it contributes to getting to Mars and doing a quality scientific mission," says Franklin, who also heads the geopolitical section of this year's Stanford study. Lusignan points out that the space station would also inhabit a much lower orbit than the seven-day staging orbit selected by Stanford for the Mars interplanetary spacecraft and that its benefits to a Mars mission would be marginal.

Use Energiya and Existing Systems

The scenario also rejects the need to develop a nuclear-powered interplanetary vehicle to fly between the orbits of Earth and Mars, as was advocated in the 1991 NASA study. The Stanford study, instead, favours a conventional, chemical rocket. The study further concludes that there is no need to develop another heavy-lift launch vehicle because the Russians already have the Energiya rocket, which can lift up to 100 tons into low-Earth orbit.

What is most important about the Stanford study is that it has developed an international mission that will use already existing systems. It concludes that there is no need to spend enormous amounts of money developing new and exotic technology.

Preparatory Missions

The study projects that a number of precursor missions will be sent up to explore the Martian surface before any humans land. NASA's Mars Observer was launched last September and will arrive on Mars in August. The Russians have projected unmanned missions for 1994 and 1996. The Stanford study projects two further unmanned missions, one to be launched in 1999 and a second, a sample-return project, designed for the years 2005 to 2008.

In the meantime, according to the Stanford study proposal, the Russian Energiya rocket will launch one half of the manned interplanetary spacecraft into Earth orbit in 2005. This half will contain the cabin module with its four floors of living space, the unloaded fuel tanks and the main rocket motors. It will be joined approximately four months later by the crew flight deck together with the crew. These parts will dock in orbit and constitute the Mars interplanetary spacecraft, which will then begin a three-year series of tests in Earth orbit.

The seven-day orbit proposed by the Stanford group is highly elliptical, ranging from 300,000 kilometres at its farthest point to 200 kilometres at its closest. It allows for a kind of sling-shot approach. The interplanetary spacecraft reaches the lowest part of its orbit every seven days and, by then, it has achieved most of the velocity that it needs to go to Mars. "If you go into the seven-day orbit, you are almost escaped from Earth's gravity field," Lusignan says.

Between 2006 and 2007, according to the Stanford study, two Mars habitat modules and a surface vehicle cargo module will be placed into an Earth-staging orbit. They will be joined by an Earth-return fuel module, an erectable structure cargo module (for greenhouses and workspace on the Martian surface) and a descent/ascent module to deliver the crew to the surface at the start of the mission and to bring the astronauts back from the surface at the end of the mission.

In the summer of 2007, these six modules will rendezvous with an Earth-orbiting fuel tanker, to take on the fuel required for the flight to Mars. In October 2007, these unmanned vehicles will be launched out of Earth orbit toward Mars, thereby supplying the Mars base in advance with the necessary facilities and cargo.

With the exception of the Earth-return fuel module and the descent/ascent module, all of the modules will land automatically at the preselected site at Candor Chasma II on the Martian surface. Both

*Based on the article 'Mission to Mars' by Raymond Hardie that was first published in *Stanford*, March 1993, pp.52-57.

the Earth-return fuel module and the descent/ascent module will remain in the Mars-staging orbit until the manned spacecraft arrives two years later.

First Manned Mission

The first vehicles of the manned Mars mission will be launched into the Earth-staging orbit in 2008 and 2009. The vehicles delivered into the Earth-staging orbit include: a new crew cabin module and crew flight deck (forming the manned interplanetary spacecraft); a third Mars habitat module and a second erectable structure module (for future base expansion); a backup descent/ascent module; and a backup Earth-return fuel module for use in emergencies. This will make a fleet of five ships consisting of one manned craft and four cargo vehicles.

In November of 2009, the Mars exploration crew and the four cargo vehicles will finally be launched out of the seven-day Earth orbit toward Mars. When the fleet arrives at Mars, it will be aerocaptured into a Mars-staging orbit. (Aerocapture utilizes the atmosphere of Mars to slow down the approaching spacecraft.) The interplanetary spacecraft then will rendezvous with the presupplied Earth-return fuel module. Once the refuelling operations are completed, the crew will dock with and enter the descent/ascent module to make the final trip to the base site on the surface. The interplanetary space-craft will be left in orbit above Mars until the return flight to Earth.

The interplanetary spacecraft will carry an international crew of three men and three women and will take nine months to reach the Martian orbit. Every spacecraft launch is planned to take advantage of the fact that the optimum time for the journey between Mars and Earth occurs only every 26 months. The rockets on the interplanetary spacecraft will use monomethyl hydrazine and nitrogen tetroxide. These are the standard liquid fuels that are used for most spacecraft. Once the interplanetary spacecraft is in an orbit that intersects with Mars, only minor navigational adjustments will have to be made.

Weightlessness and Radiation Exposure

The Stanford-designed spacecraft offers solutions to two of the major problems confronting interplanetary travellers, long-term weightlessness and exposure to interplanetary radiation.

The deleterious effects of long-term weightlessness have been well-documented by the Russians on board the Salyut 7 space station. Oleg Atkov, the first physician to fly in space, spoke to the Stanford team last year and documented how prolonged weightlessness can cause the deterioration of the cardiovascular system and the shrinkage of bone mass. As a result of these consultations, the Stanford study proposed tethering a five-ton counterweight at the back end of the cabin module and reeling it out to a length of 200 meters. When the interplanetary spacecraft is on its way to Mars, it will spin about the extended counterweight at a rate of four revolutions per minute, resulting in one-third artificial gravity (equivalent to that on Mars) and, ideally, a happier, healthier crew.

The other major hazard that the crew will face is radiation. The 80-ton spacecraft will shield the crew from normal doses but there is still the danger of solar flare radiation. To combat this, the lowest compartment of the spacecraft is designed as a storm shelter that is surrounded by a 17-ton shield of water contain-ed in the outside walls. Solar flares would be expected to occur once or twice at the maximum during the nine-month journey, and the crew would have approximately 20 minutes warning in which to get into the storm shelter.

The crew will be on Mars for approximately 14 Earth months (the Martian year is 687 Earth days) before using the ascent vehicle to take them back into Mars orbit and a rendezvous with the interplanetary spacecraft. By that time a second crew will be on its way to Mars in another interplanetary spacecraft. The colonization of Mars will have started.

Political Reality

The technical aspects of the plan are relatively straightforward. It is the residue of Cold War politics that is causing the headaches. In every case, the Stanford study chose the simple and less expensive over the complex and more expensive. And yet, frequently, simple is not as simple as it seems.

Arguably, the most politically volatile part of the Stanford plan is the proposal to use the Energiya, Russia's massive heavy-lift launch vehicle. Lew Franklin says that Stanford's "whole proposal to use the Energiya, even though it is in the next century is, in today's world, still a revolutionary idea. And it would be proper to characterize this as one of the controversial arenas that the University has found itself in by merely looking at what is available in the world".

Why would the Stanford team propose using a Russian rocket over one constructed in the United States? Quite simply, the United States does not, at present, possess such a heavy-lift launch vehicle. The Titan IV, which is currently being used almost exclusively for military launches, can lift approximately 18 tons. This is in sharp contrast to the Energiya which can launch 100 tons into a low-Earth orbit.

It has been estimated by NASA and the US Air Force that the cost of developing a US equivalent to the Energiya would be at least \$12 billion. That would also add five years to the timetable and five years to the budget. This National Launch System, as it has been called, is still in the early stages of planning, whereas the Energiya comes with its development costs already paid. The Stanford study has calculated that each Energiya launch will cost approximately \$250 million.

There are, however, still many political objections 'cloaked in other guises' to the use of Russian technology. In an article in *Space News* on July 14, 1991, Space analyst Ed O'Grady stated: "Energiya is clearly an unproven vehicle," given only two flights in two years. And in a July 9, 1991, article in *The New York Times*, Jerry Grey, director of science and technology policy at the American Institute of Aeronautics and Astronautics, said, "As a political decision it would make a great deal of sense, but as an engineer, I'd hate to carry it out. Just matching up payloads to the rocket would not be easy. Everything has to be compatible". The problem of compatibility is a complaint that is voiced by a number of US space engineers.

Most objections to cooperation with the Russians are, however, less technical than they are political. James E. Olberg, the author of *Red Star in Orbit*, highlighted this in *The New York Times* article of July 9, 1991: "We spend aerospace money in our country as a matter of policy. We want to enhance our own industrial capacity. It's not in the cards that we're going to realign our whole programme to foster their [the Russians'] political stability, even though it is probably the most rational thing to do".

Olberg expresses an opinion that is very much alive in this country. The Cold War may be over but old attitudes and vested interests do not just disappear overnight.

The decision as to whether the world's space efforts are to remain national or become international is still in the hands of the politicians. But the Stanford study has shown that there is the possibility of a new direction. Lusignan and his class are currently in the midst of their sixth Mission to Mars study, evaluating the "space assets of the entire planet". According to Lusignan, this present study will "briefly review the mission architecture, will review in some detail the issues of international interaction and will design in detail the major vehicles required for the mission". But Lusignan, his class and his international guests are well aware that the decision to go to Mars or not is political rather than technological.

Why we would want to go to Mars is another question. Boris Gubanov, the designer of the Energiya, in a 1991 interview with *The New York Times*, said, "Young people will hate us for not making a decision to go to Mars. To have on our planet this technology and not use it for all the countries is not good".

Conclusion

The Apollo mission to the Moon became a catalyst for technological innovation and changed forever our view of our fragile, blue-water planet. An international mission to Mars would underscore that we are one world. And as we travel further out into space and see that tiny and exquisite liquid-blue marble called Earth slowly turning in its orbit, that metaphor becomes more and more powerful. Whether it is for the metaphor of internationalism, scientific knowledge or the acceptance of our destiny as citizens of the solar system, it is generally accepted that one day we will be on Mars. The only question is whether it will be this generation or the next? The technology is there already and the work of the Stanford study gives a golden promise of an international future.

Colonizing Mars

The New Human Migration

From the beginning mankind has treated the Earth as if it had infinite resources. Only now do we realize our world is both overpopulated and showing the limitations of its natural resources. Even worse, it is possible through nuclear war or simple stupidity that the Earth's environment could be severely damaged. Unfortunately the Earth is not as safe as we once thought it was. With this sobering insight, it is worth considering going beyond the Earth to establish an alternative resource base.

BY GARY A. ALLEN, Jr *
Prentice Centre,
The University of Queensland, St Lucia,
Queensland

Introduction

The three worlds closest to the Earth are the Moon, the planet Venus and the planet Mars. These three worlds have been the subjects of intensive scientific investigation. The planet Mars alone has had twenty six spacecraft sent to it. From these investigations it can be established that Mars is the most suitable world for an independent self-contained colony.

The surface pressure of the Martian atmosphere is about 8 millibars which is equivalent to the pressure of the Earth's atmosphere at about 30,000 meters. An atmosphere of this pressure is too thin to breath but does provide protection from the solar wind and primary cosmic rays. Due to its density, the atmosphere of Mars has a low heat capacity. For example, the noon time summer temperature at the Martian equator is a comfortable 20 degrees centigrade but during midnight the temperature drops to -100 degrees centigrade.

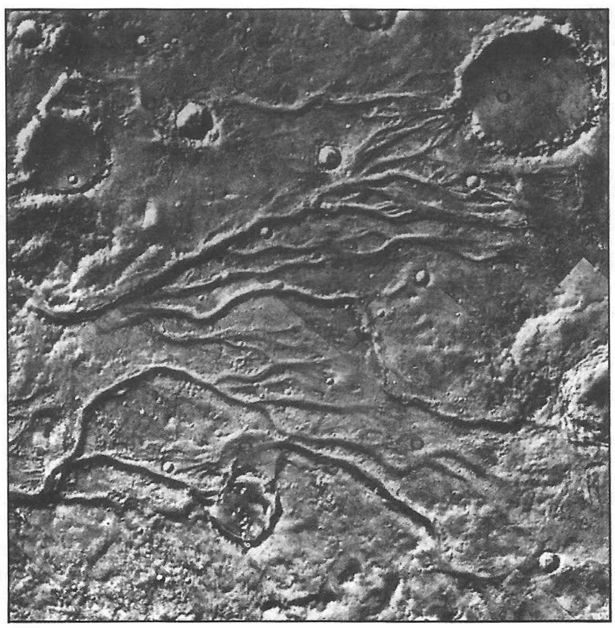
The two Viking spacecraft which landed on the surface of Mars indicated that the Martian soil probably contains all of the elements necessary for terrestrial life (some trace elements were outside Viking's measurement range). These results indicate that Mars could be a site for colonization unlike the Earth's moon which lacks such vital elements as nitrogen and carbon.

Water on Mars

There are many dry river beds and alluvial fans on the surface of Mars which can easily be seen from orbit. The study of these river beds has left little doubt they were produced by water and not by lava or wind as was first believed. However this is a difficult conclusion to accept since the current atmospheric pressure of Mars is below the partial pressure of water which is 24 millibars. Because the atmospheric pressure is so low, water will boil if left exposed on the surface of Mars.

Many theories have been proposed to explain this apparent contradiction. The theory which I am most inclined to accept is that the Sun's luminosity varies slightly over hundreds of thousands of years causing significant changes in the planet's surface temperature. This variation in solar intensity could explain why the Earth has periodic ice ages or high temperature episodes when the ice caps melt completely. Mars has ice caps but they are not thick enough to explain these river beds.

Mars probably has a thick permafrost layer in its soil. If the temperature of Mars were to be increased, this permafrost layer would sublimate to water vapour thus increasing the pressure of the Martian atmosphere. This process could continue until the atmospheric pressure was higher than 24 millibars thus allowing for the formation of rivers.



One of the great discoveries was the existence of channels on Mars. Although several theories have been put foward concerning their origin, the leading one proposes that these channels were caused by catastrophic floods of liquid water. Many of the outflow channels are geologically quite old and consequently indicate a greater amount of water available in the past. This is thought to be an indication of long-term climatic changes on Mars.

There is photographic evidence supporting the belief in a permafrost layer in the Martian soil. Naturally the widespread availability of water on Mars would greatly simplify the establishment of a colony and might ultimately make it possible to terraform Mars.

The Red Planet

The Viking landers also indicated that Mars is rich in heavy metals such as iron. The primary mission of the Viking landers was to detect life on Mars. In pursuit of this goal both landers were placed on dry river deltas. In both cases the landers reported five times as much iron in the soil as would have been found in typical terrestrial sedimentary soil. The reason why Mars is the "Red Planet" is because the whole world is covered with rust.

Locked-up Oxygen?

The Viking landers reported back an ambiguous result concerning life on Mars. They found when water was added to the Martian soil a gas evolved from a chemical reaction. However it was also found that this same soil contained no complex organic molecules. It is now believed that Mars is lifeless, the gas-producing chemical reaction being a consequence of peroxides in the soil such as hydrogen peroxide. If this is true then Mars would be almost ideally suited for industrial development, for hydrogen peroxide is an excellent energy source (it has been used as rocket fuel).

One scenario is hydrogen peroxide could provide the energy for converting atmospheric carbon dioxide into carbon monoxide. The iron oxide from the Martian soil could then be reduced by the carbon monoxide into pure iron in an electric furnace and could then be made into steel. The two "waste products" from the hydrogen peroxide reaction (which is a single fuel, catalytic process) are pure oxygen and steam, both of which would be valuable resources for the colony.

Martians by 1985 !

The notion of establishing a permanent base on Mars is not a new idea. In 1970, President Richard Nixon was presented with a plan following the Apollo program which would have established a settlement on Mars by 1985.

Preliminary estimates put the project cost at about sixty billion dollars. At the time the United States was in the early phases of withdrawing from the Vietnam War which cost about $250 billion. After the successes of the Apollo program which cost about $20 billion the American people were bored with space. The commonly stated view then expressed was: "Why are we spending so much money on space when there are so many problems on Earth?". Unfortunately these events

* This article was first published in *Australasian Science Mag*, a general science magazine from the University of Southern Queensland, Australia.

resulted in the Mars program never being initiated.

Recently President Bush called for a program to send people to Mars which he called the "Space Exploration Initiative" or SEI. However SEI received little actual backing from Bush beyond his simply proposing it. SEI was later effectively killed in Congress. Since the Apollo program there has been several privately funded conferences on the issues of Mars exploration and settlement (the so called "Case for Mars" conferences in the United States are among the best examples). However as of now there is no active plan currently funded by the United States government for the colonization of space.

Setting up the Colony

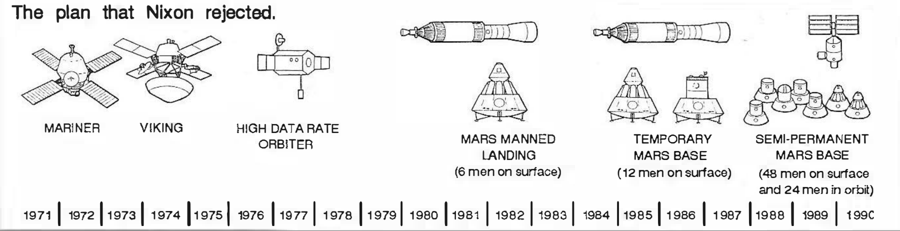
It is interesting to speculate on how the colonization of Mars could take place. If I were to plan such a project I would organize it in four steps covering a period of two to three decades.

The first step would be to send a team of about twenty pioneers in vehicles with the capability of returning to Earth. The journey to Mars would take 350 days if they employed a Hohmann transfer orbit (a minimum energy orbit) or about 100 days if they used a nuclear thermal rocket (NERVA technology). The pioneers would employ artificial gravity during their interplanetary transfer. The pioneers on the surface of Mars would initially live in their spacecraft and construct habitats for 100 people using inflatable prefabricated structures.

The next step would entail 100 colonists transferring in zero gravity using comparatively inexpensive one way vehicles. No return to Earth would be allowed for. The "no return" aspect would not only greatly reduce costs but would also make political termination of the project more difficult prior to colony self sufficiency. The one way vehicles would plunge directly into the Martian atmosphere from interplanetary orbit using navigational assistance from the pioneers. The vehicles would be brought to the surface using parachutes combined with either retro rockets or an air bag system (such as planned by JPL for the MESUR spacecraft, see ***Spaceflight***, June 1993, p.209). The pioneers would then assist the 100 colonists from the now useless vehicles and place them into waiting habitats. The colonists would initially be suffering from the effects of having been in zero gravity for many months and would need the help of the pioneers to regain condition. Fortunately the gravity of Mars is 37% of the Earth's which would allow for an easier recovery and be sufficient to prevent later bone decalcification and muscle atrophy. Once the colonists were fit, more new habitats would be constructed.

Next 500 more colonists would be transferred to Mars. Then, after they had regained their full fitness, one last wave of colonists would come to bring the total population to slightly over 1000 people, a population sufficient to avoid inbreeding.

The plan that Nixon rejected.



The original technology that the early colonists would bring to Mars would assume resupply from Earth. Their habitats would be little more than holes in the ground with air tight fabric liners. The colonists first task would be to establish an Earth independent technology and develop habitats based entirely on local materials and manufacture. I do not believe this new Martian technology could be worked out on Earth since there are too many unknowns. The colony on Mars must first be established and from its various learning experiences, the new technology could then be developed with assistance from Earth.

Valles Marineris, the huge canyon of Mars, would stretch across the whole of Australia - a distance of about 5,000 km. It has a width of approximately 240 km and depths of up to 6.5 km. The Grand Canyon is only the size of one of the tributary canyons of Valles Mariners. *NASA*

The establishment of the Earth independent technology would conclude the third step with twenty colonists returning to Earth in the original pioneers' vehicles thus cutting the umbilical cord with Earth.

The Martian Neighbourhood

The fourth and final step would be to construct large and spacious habitats. For example I foresee the entire Valles Marineris being covered over by a large transparent glass ceiling supported by air pressure. The Valles Marineris is a huge canyon system which makes the American Grand Canyon or the African Rift Valley look like a small ditch in comparison. The glass ceiling would use suspension bridge type cables and towers for its construction and backup support in case the habitat's air pressure was accidentally lost. The glass itself could be quite thick or double layered with circulated heated water between the panes. The glass would have to be strong enough to allow people to walk across it or drive vehicles on it.

The whole Valles Marineris canyon system could be pressurized and heated, providing a comfortable and natural Earth-like environment. The construction process would start from one of the smaller side canyons of the Valles Marineris and grow into the main canyon as the population grew. For a variety of reasons these habitats should have a central artificial river flowing down the middle with the water recirculated through an aqueduct system parallel to the canyon. The water would be heated keeping the habitat at uniform temperature and humidity.

The habitat would be partitioned along the length of this river. At the river's "source" the partition would have a pure Martian atmosphere mechanically compressed to one atmosphere pressure and heated to 20 degrees centigrade. The Martian atmosphere is 95% carbon dioxide and 2.8% nitrogen but has no free oxygen. The source partition would be full of vegetation utilizing the carbon dioxide but could have no animal life. The soil for this vegetation could be fertilized with urea manufactured from the atmospheric constituents. The soil itself could be tailings produced from the strip mining for peroxides. The atmosphere of the source partition would be slow leaked through a wall into the next partition down river. The river itself would flow underneath this wall through air tight sluice gates. The next partition would have some oxygen resulting from carbon dioxide metabolized by the plant life in the previous partition. The more oxygenated air from this partition would then be leaked into the next partition to be further enriched with oxygen until the oxygen level was high enough to safely support animal life.

The principle of continually pumping in air to pressurize a leaking container is the same method used in pressurizing a commercial aircraft such as the Boeing 747. An important engineering issue for the Mars colony would be to make the whole system safe from any single point failure and most double point failures. This could be achieved by networking the aqueducts correctly and making liberal use of pressure actuated air tight gates.

What will it Cost ?

The basic technology for establishing a Mars colony has existed for twenty years. There is no technological barrier against the colonization of Mars. The cost of a program to explore Mars varies depending on who you talk to.

As mentioned earlier the original Mars program rejected by President Nixon cost about $60 billion. A study recently performed at the Lawrence Livermore National Laboratory put the price at about $10 billion which is certainly too low. Opponents to manned space exploration like to quote a price of $500 billion.

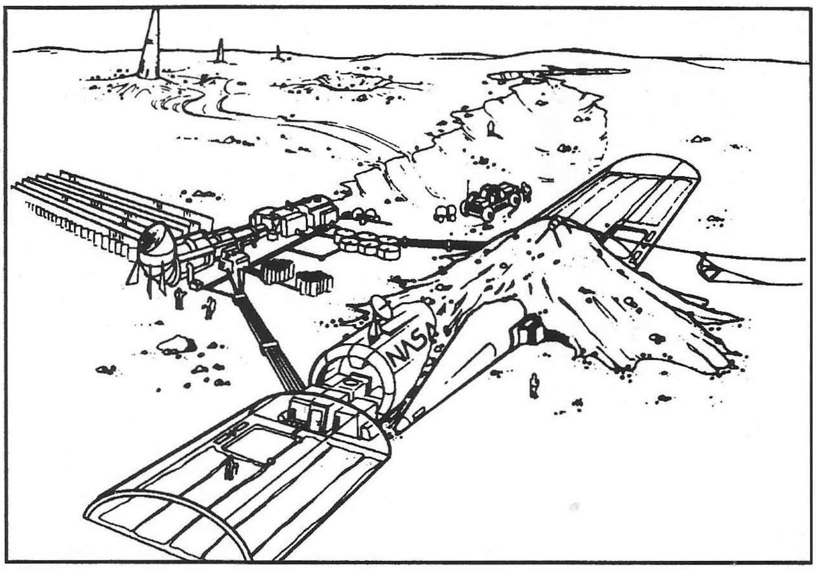
My own opinion is the price to colonize Mars is somewhere between $60 and $100 billion. This is an almost inconceivable amount of money. However a comparable amount of money was recently spent on the Persian Gulf War, and about twenty times this amount was spent on the military buildup during the Reagan administration. The money is there if people can be convinced to spend it.

Unfortunately one of the principal problems with getting people to Mars is due to its being promoted as an exercise in pure science. This is clearly the wrong approach. For the same amount of money spent on manned Mars exploration one could probably develop a cure for cancer or come up with a working artificial heart or solve the nuclear fusion problem or decipher the entire human DNA or deal with any other worthy research problem. Mars exploration would always take a lower priority to these other scientific issues.

If we are to get people on Mars then the concept must be sold as an exercise in colonization and not as a purely scientific activity.

Since ancient times colonization has always been viewed as the moral equivalent of war. In the past, societies have invested a large percentage of surplus national wealth in forming colonies. Despite the high costs Mars can be sold as a venue for colonization.

I might add in passing that considerable good planetary science would also be done as a by-product of colonizing Mars.



A vital component of a permanent base will be a gas extraction system to convert carbon dioxide into oxygen for life support systems and fuel production.

The New World

If one assumed the population doubled every twenty years (as it currently does in many third world countries) then a colony of initially one thousand people could increase to a population of one billion after four centuries. Mars has the same land area as the Earth despite its smaller size because Mars has no oceans. Once a population had reach one billion then a program of true terraformation could commence. Terraformation could be organized as a by-product of the Martian economic development. All industrial activity could be oriented towards maximum out-gassing and heat production.

Once the atmospheric pressure increased to 24 millibars, the ancient rivers would flow again. The presence of liquid water would allow for the introduction of genetically modified life forms which in turn would accelerate the conversion of Mars into a more habitable world. With the establishment of local industry the Mars inhabitants could return to Earth in spacecraft manufactured on Mars or begin the development of other worlds in the Solar System.

Whenever the inhabitants on Mars saw the Earth as a blue evening star they would be reminded that their ancestors were astronauts. Just as pioneering is an important part of our culture so space travel would be an important part of theirs. Certainly the inhabitants of Mars would feel compelled by their heritage to spread across the Solar System taking their terraforming technology with them.

Let's do It Now

People normally like to sell things based on some sort of immediate benefit. Unfortunately colonizing Mars would not provide any short term economic return or reduce present day human suffering. It would be hundreds of years before a Mars colony could be economically significant to the Earth. However I am convinced a thousand years from now most human industry and technological development will occur on Mars with the Earth being primarily a pastoral world.

Now there is a subtle and dangerous point that needs to be understood. Until recently there has been the view that the world's economy would always improve and if we continued to wait then with a stronger economy and better technology, colonizing the planets would become cheaper and easier. However what if the opposite is true?

If we persist with the notion that we will not colonize Mars until the economy improves but because of over population and resource depletion the economy only gets worse, then the day must ultimately come when we will no longer have the capability to colonize Mars or any other place.

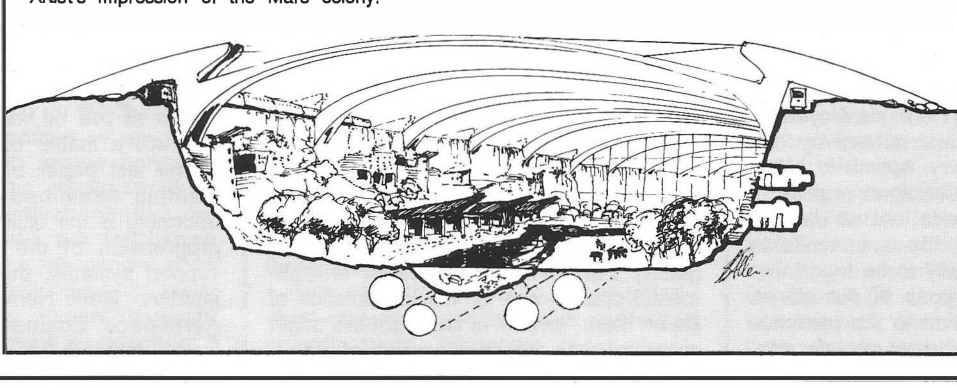
One can make a convincing argument that economic regression is unavoidable because the current world economy and population levels are based on the consumption of nonrenewable resources, i.e. fossil fuels, intensive agriculture, etc. Once these nonrenewable resources are depleted then the world's economy and population levels must reduce down to levels sustainable through renewable resources. However it is unlikely that such a future no-growth, agrarian society could mount a major technological project like colonizing Mars.

Consequently there is a "window of opportunity" for colonizing Mars which opened in 1970 but will probably close sometime in the next century when the economic capability to colonize Mars ceases to exist.

If we have not colonized Mars by that time then we may have lost the opportunity forever.

It has been our incredible good fortune to be the generation which can establish mankind's presence on another world. This would represent the greatest adventure experienced by mankind since our ancestors left Africa. However this opportunity will not last forever. If it is our destiny to go beyond the world of our birth and inherit the stars then we must seize this opportunity.

Artist's impression of the Mars colony.



Bringing Worlds

Terraforming - the New Science of

Organized jointly by the Centre of Extra-Mural Studies (Birkbeck College, University of London) and the BIS a two day weekend school on the subject of terraforming 'Bringing Worlds to Life' took place in London on 15-16 May. The meeting broke new ground in at least two ways. It was the first time that the subject of terraforming had been accorded recognition as an important area of scientific study by any UK University and it was also the first time that the Centre and the British Interplanetary Society had collaborated in organizing a weekend school with the aim of widening interest in a space-science related subject.

BY RICHARD L. S. TAYLOR
Centre of Extra-Mural Studies, Birkbeck College, University of London

Unconscious Terraforming - the Human Impact on the Earth's Environment

The first two sessions, ably chaired by Len Carter, were concerned with the human impact on the Earth and our current knowledge of the nature and resources of Mars.

Opening the proceedings Dr Andrew Warren (University College London), an internationally recognised authority on desert environments, examined the problem of the human impact on Earth. He showed how desert margins can be used as sensitive indicators of climatic and environmental change. They allow perceived changes in the Earth's climate and environment which are often assumed to constitute unambiguous evidence for the impact of human activity on the Earth, to be assessed and evaluated. While it was clear that certain forms of human activity do have a massive effect on the environment Dr Warren urged that we must be careful not to jump to the conclusion that all major changes in the environment are attributable solely to a human agency.

Deeper examination of the many factors involved reveals a far more complex situation than initial assessment might suggest. In many instances it had turned out that the supposed human effects on the environment were only minor in scale but that they were coincident with the often entirely overwhelming forces of natural environmental change. Clearly we sometimes tend to overestimate the power of human activity as an agent of environmental change. The terrestrial ecosystem is a highly developed and complex system filled with countless self-correcting feedback loops and in overestimating our ability to impact on the Earth's environment we might also be greatly underestimating the difficulty of deliberately transforming the present conditions on Mars to a more Earth-like state.

The second speaker Professor Robert Marrs, (Director of the Ness Botanical Gardens, University of Liverpool) discussed the use of restoration ecology techniques for re-establishing ecosystems on areas of the Earth destroyed by mining and other industrial activity. On the whole he was very optimistic about our ability to restore damaged regions of the Earth on the grounds that all the materials necessary for life are available and that they are usually to be found surrounding damaged regions of our planet.

A degree of adaptation to the presence of toxic substances (heavy metals contamination) had already been found to exist in nature. This discovery allows new strains of plants tolerant to specific toxins to be developed. In the longer term it may be possible to produce genetically engineered varieties of plants capable of growing in extremely hostile environments. That being said, he considered the problems of reclaiming Mars for life to be a task of quite a different order.

On Mars it would not be a case of restoring life to a damaged ecosystem but of starting over anew. Comparison of the present bio-geophysical process operating on Earth with the available resources on Mars led him to the conclusion that nitrogen was the critical element. The amount of nitrogen known for certain to be present on Mars was so low that it would be difficult, or perhaps even impossible, to implant any form of terrestrial life on the planet. It was a case of find the missing nitrogen before we can be certain of bringing Mars alive.

The Mars Environment

The morning session closed with a discussion of the nature and resources of the surface of Mars.

Professor Claudio Vita-Finzi (Head of the Research School of Geological & Geophysical Sciences, Birkbeck College and University College London) expressed the opinion that there is still considerable uncertainty regarding the long term stability of the present surface and climatic conditions on Mars. Both the periodic changes in the eccentricity of the Mars orbit, and in the axial tilt of the planet, produce significant departures from the climate and the environment we currently observe.

It has to be remembered that the timescales for some of the climatic cycles on Mars are quite short, geologically speaking, for example, the seasonally permanent ice caps switch from one pole to the other every ~25000 years. Waiting for a more favourable climate on Mars will greatly reduce the energy requirement necessary to free the volatile resources of the planet. This could prove to be the cheapest and most advantageous way of getting started a programme of environmental change and for the implantation of life on Mars - even if at first sight this might seem to be a rather unexciting strategy.

To Live Away from Earth

The afternoon session, chaired by Geoffrey Epps (Astronomy Lecturer, CEMS) was devoted to an examination of the why and how of living away from Earth.

The opening speaker was Peter Ceresole (BBC Horizon Science Producer) the writer and producer of the Horizon programme *Mars Alive* which was broadcast early in February. He gave an amusing and highly informative talk in which he examined the reason why, all over the world, teams of scientists and individual researchers are tackling the science of getting to Mars and transforming it into a living planet.

For the Japanese it was an intellectual exercise to stretch the mind and to keep scientific staff motivated by preventing boredom with day-to-day scientific work. For the Russians, in a time of the virtual economic collapse of the space programme, it is a way of securing a future for themselves and their accumulated expertise - a Mars project is a meal ticket. For the Americans the idea of taking life to Mars is largely a creative, ethical matter, a climax to what it means to be human. To the British, lacking any integrated space programme of their own, it is a giant thought experiment and perhaps a substitute for the real thing.

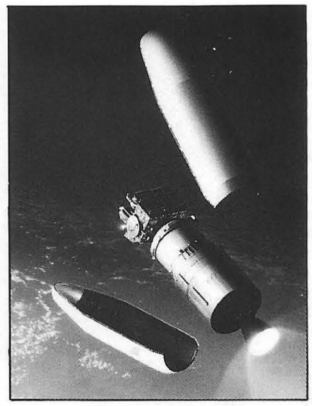
But above all the justification for terraforming is that it is a mind-extending scientific challenge that brings together a huge and diverse range of disciplines which can throw light on any number of problems.

Dr Robert Parkinson (British Aerospace Space Systems) looked at the space infrastructure that would be necessary before the material resources of the solar system could be discovered and exploited as part of a drive to colonize or terraform other planetary bodies. He showed that the development of more advanced forms of space transportation was a vital first requirement. Such systems can be expected to radically change our capabilities but what these developments might lead to was not so easily foreseen. Whether it would lead to new worlds to live on, or new ways of living, was still a matter of conjecture.

The last paper of the first day of the meeting examined the idea that terraforming is the ultimate step in a steady progression of the development of life support systems, that is habitable space facilities. Mark Hempsell (Department of Aerospace Engineering, University of Bristol) argued that the current approach

to Life

Planetary Environmental Engineering



to the problem of terraforming viewed it largely as an isolated activity which was entirely self-contained, but in practice, he suggested, only a society which already possessed a very large space infrastructure would be in a position to undertake such large projects. He outlined how the progressive development of life support environments could be extended from the concept of the simple space-platform right through to the point where the entire environment of a planet could be made habitable.

Terraforming - The Bio-Geophysical Approach

The second day was chaired by Dr. John Potter, (Editor, The Environmentalist) and the morning session was concerned with the bio-geophysical approach to terraforming.

The proceedings opened with a videotaped lecture specially prepared for the meeting by Dr Christopher McKay (NASA Ames Research Center). Dr McKay is a powerful advocate of the biological approach to terraforming Mars and presented almost totally convincing arguments that the planet can be gently persuaded back from its present hostile environmental state to one of more clement climatic conditions, perhaps similar to those the planet may have enjoyed in the distant past.

He envisages starting this process of transformation by inducing global warming, in the first instance through the introduction of powerful greenhouse gases, CFCs, into the present Martian atmosphere. Following this one major act of human intervention, Dr McKay believes that the release of frozen CO_2 and other volatiles entrained in the regolith and crust would produce a progressive and self-sustaining transformation of Martian conditions to the point where the planet would at least be able to support fairly advanced plant life. He remarked that it might be possible to maintain the presence of the necessary levels of super-greenhouse gases by genetically engineering microbial, or plant, species to produce the required CFC greenhouse gases rather than having to manufacture them industrially on Mars.

Although the biological scenario envisaged by Chris McKay is a slow process taking perhaps 100, 000 years to produce an atmosphere of Earth-like composition, he expressed doubts regarding the value of some of the more technologically aggressive methods proposed for making Mars habitable. It is his belief that a terraformed Mars is more likely to result from the decision of colonists living in permanent scientific bases and other colonies on the planet rather than as a result of a deliberate Earth-directed programme of planetary transformation.

Martyn Fogg (Probability Research Group) presented a paper which placed great emphasis on synergistic processes as agents of planetary environmental change. He stressed that if the aim was the permanent settlement of Mars a fully terraformed planetary environment offered enormous advantages over enclosed life-support systems that are generally envisaged in conventional plans for space colonies and bases.

As in the case of the Earth a terraformed and largely self-sustaining Mars ecosystem would provide virtually for free the necessary background life-support. He believed that the initial stages of terraforming could only be carried out in a reasonable period of time through a greater degree of technological intervention in the geophysical system of the planet than advocated by Chris McKay. Energy was required to achieve the rapid release of water and atmospheric volatiles from depth within the crust. Thermonuclear explosives were the most economical and viable means of injecting this necessary energy into the Martian crustal rocks precisely where it was needed. The release of substantial quantities of volatiles in this way would in turn provide the conditions that will allow the establishment of synergistic bio-geophysical processes that can provide both the means of environmental change and, eventually, of minimizing the degree of continuing intervention required to maintain the newly established ecosphere in the desired state of equilibrium. Martyn Fogg pointed out that although the commencement and completion of any terraforming project may be centuries away the subject had immediate relevance to planetology and has exciting possibilities in education.

Constructed Environments - Engineering and Technologically Intense Solutions to the Problem of Habitability

The final session consisted of two papers which considered engineering and technologically intense solutions to the problems of habitability.

The first, presented by Richard Taylor (CEMS, Birkbeck College), concerned itself with how a fully humanly habitable environment can be established and maintained on Mars if insufficient volatiles are present to allow a gravity bounded atmosphere of terrestrial composition and surface pressure to be produced.

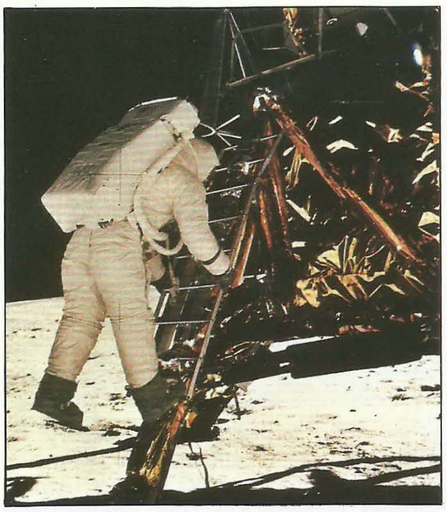
He described the Worldhouse solution - which basically consists of constructing a planet-wide gas-tight roof over the greater part of the planet's surface - as entirely possible within the limits of existing materials and civil engineering technology. In comparison with conventional terraforming scenarios a 3km high worldhouse would require only about 10% of the quantity of atmospheric gases for a gravity bounded atmosphere. An additional advantage is the fact that the roof plays a significant part in securing the increase in temperature necessary to make the planet habitable, an increment in excess of 50° C is quite easily achieved.

Once constructed, the deliberately restricted ecospheric environment within the Worldhouse is largely self-regulating and behaves in a way closely similar to a completely unconstrained planetary environment. This results from the fact that the enclosed planet-wide environment experiences simultaneously, within it, different seasons and night and day. The disadvantage lies in the fact that there is a continuous technological overhead of roof maintenance, and a need to provide ways for overcoming possible hazards to the integrity of the completed structure.

The final paper ensured that the meeting went out in a veritable blaze of scientific imagination. Everything presented by former Jodrell Bank Radio Astronomer Paul Birch was scientifically and mathematically possible. The construction of supra-mundane planets, vast decks supported by mass streams at the 1 'g' level over gas-giant planets, Jupiter for example offering a habitable surface area 318 times that of the Earth. Systems illuminated and warmed by a giant soletta mirror were just a minor part of the range of technological fixes which Paul Birch assured us were technically possible.

The enthusiasm and enjoyment that some of these ideas engendered brought a highly successful Weekend School to a close. Summing up the proceedings Dr. John Potter said that for him the great advantage of studying a subject like terraforming lay in its multi-disciplinary nature. In the two days of the school there was hardly any branch of science that had not been touched upon. If Mars were ever to be made habitable he personally preferred the idea of tweaking the planet's existing environment. Persuading it gently to follow a biologically sustainable course to a fully functional ecosystem. For this amongst other reasons he preferred the term planetary eco-engineering to that of environmental engineering which, he thought, did not place sufficient emphasis on the importance of living processes in any future plans for making other worlds habitable, or indeed for maintaining our own home planet in good condition.

This first school on terraforming was rated such a success that it is hoped to organize further collaborative meetings, possibly on an annual basis, and to publish the papers probably in ***JBIS***.



Astronaut Edwin E Aldrin Jr., Lunar Module pilot, descends the steps of the Lunar Module ladder as he prepares to walk on the Moon. *NASA*

SPACE '93 Welcomes Lunar Astronaut Buzz Aldrin

The British Interplanetary Society Celebrates its 60th Anniversary

at

White Rock Theatre, Hastings, E. Sussex

15-17 October 1993

Among the special guests and visitors to this weekend meeting will be Buzz Aldrin who on 20 July 1969 became the second man to walk on the Moon.

He will be an after-dinner speaker at the Anniversary Dinner of Saturday, 16 October and will be participating in the satellite link-up between Patrick Moore in Hastings and Arthur C. Clarke in Sri Lanka on Sunday, 17 October.

Live Satellite Link-Up - Hastings to Sri Lanka

(Courtesy of INTELSAT and BT)

Sunday Buffet: To be held in the Sussex Hall of the White Rock Theatre, the venue of the satellite link-up. The buffet will be provided courtesy of British Telecom.

Close: At 5 pm on Sunday, 17 October.

Registration: For information on the programme, accommodation and other arrangments, please contact The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Open to Members and Non-Members. Members enjoy a discount on rates.

Arthur C. Clarke with Patrick. Moore at a reception in London in July 1992.

RECEPTION

Friday Evening, 15 October

Do not miss this special event at

Marina Pavilion
St. Leonards-on-Sea

to which all participants are invited (free-of-charge).

Buffet together with entertainment will be provided.

Test firings of solid rocket motors and liquid propellant rocket engines are carried out again and again to guarantee operational performance. *Royal Ordnance*

The third one-day visit to be arranged during the Society's Diamond Jubilee year was on 14 July when a group of members visited a part of Rocket Motors Division of Royal Ordnance plc (which itself is a division of British Aerospace Defence Ltd) at Westcott, Bucks.

Managers Peter Midgley and Tony Klepping welcomed the visitors with coffee and biscuits in the conference room and with the aid of slides a review was given of the history and evolution of the Westcott unit from 1946 when it assumed responsibility for solid and liquid-fuelled rocket motor design and testing.

At Westcott there are facilities for the manufacture, processing, storage, conditioning, testing and firing of solid-propellant rockets and boosters up to 36 inches in diameter and up to 1 MN (or 225,000 lb) thrust. Plastic propellant is pressed in rocket motor casings to give a star shaped cross section charge design which allows for a controlled thrust time performance.

There is specialised plant for winding glass or graphite filaments alone (or with steel strips to form multi-layers) to provide additional lightweight strength to rocket casings. Rocket test capabilities include vibration, centrifugal, temperature and pressure conditioning and drop testing up to 40 feet. Non-destructive testing is also achieved with X-ray and ultrasonic radiation.

The first visit of the afternoon was to the solid propellant laboratory, now used to house an exhibition of solid-propellant motors including most of those which have formed parts of the numerous marks of the Skylark sounding rocket. The 425th Skylark launch took place in June 1993.

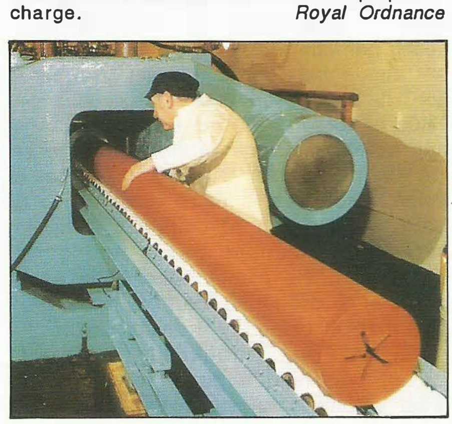
Next, K site was visited where the visitors donned safety helmets. Installed in the firing bay was a Sea Dart solid-propellant booster, one of a number containing time-expired charges due for refilling. The charge was to be burned out (fired) before the casing was cleaned and refilled. The control room not only controlled the visual and audible warning system and firing but also housed the electronic equipment for recording various parameters such as temperature, thrust, duration, etc as might be required by the customer (the Royal Navy in this instance).

The group retired to a safe vantage point to witness the firing and, although it lasted for only about 4 seconds, there was general amazement at the force of such a relatively small charge. The need for blast walls was obvious and the amount of flame, smoke and noise created a healthy respect for the safety precautions. This was undoubtedly the highlight of the visit to Westcott.

The next port of call was F site where the liquid-fuelled rocket test facility was housed. As such motors are usually required to work in a vacuum or near-vacuum conditions, the firings take place in a vessel from which air can be expelled by powerful pumps. Examples were seen of bipropellant motors in which the two propellants ignite on contact and members were surprised at the accuracy of the drilling of numerous jets of sub-millimetre diameters in the titanium injectors.

The final visit was back to the conference room where the group was refreshed with afternoon tea and discussion. Ex-

Extrusion of double base rocket propellant charge. *Royal Ordnance*



Congratulations to...

George E. Mueller on reaching his 75th birthday. He is a long-standing Honorary Fellow of the Society and was formerly NASA Associate Administrator for Manned Space Flight. The first public announcement of the details of the Space Shuttle program in this country was made when he addressed a special meeting of the Society. He is currently President of the International Academy of Astronautics, Paris.

William A. Reupke, a Fellow of the Society, whose paper, *The Rocket Pioneers and Atomic Energy*, published by the Society in 1992, has been selected in a CSC (Computer Sciences Corporation) Systems Group judging as a winning technical paper.

Henry Matthews, Assistant Editor of the AUB Bulletin (Beirut, Lebanon)) and author of *The Encyclopedia of Rocket Aircraft and Space Shuttles*, a 370 page book in Arabic, recently named as co-winner of the prize for Best Arabic Scientific Book by the Kuwait Foundation for the Advancement of Sciences. Mr Matthews, who is a Member of the Society, says that he will be in Kuwait in November to receive his award and that in his comments there he will stress the importance of the contribution made by the BIS to the spread of interest in space flight.

pressions of gratitude followed for a most interesting and entertaining day, a visit which members will long remember.

Correspondence

Sir, I would like to express my sincere appreciation to everyone concerned for the time and effort, which was devoted to the arrangement of the visit to Westcott. I feel sure that in this I speak for the other attendees.

The whole day was literally delightful, comprising presentations covering the history of the site and its sister sites and the development of rocket motors within Royal Ordnance, which incorporated two short videos.

A buffet lunch was followed by a satisfyingly long browse in the rocket motor exhibition and then some very exciting visits to motor test sites, including a solid propellant motor firing (minus nozzle). The earth moved for me, and even the rain held off.

I would particularly like to thank our two hosts for the day, who were at the same time informative and refreshingly relaxed, or should I say, interruptable.

It was sad to note the reduction in numbers of employees at this site over the last several years, at least partly as a result of the thawing of the cold war, but history will probably demonstrate the need for such expertise again.

J.H. POWELL FBIS

Sir, I would like to thank you for arranging the visit to Westcott recently. It was an extremely interesting day, perhaps the most memorable event of the day was the firing of a Sea-Dart rocket.

Could you pass on my thanks to all those responsible.

M.A. COWELL FBIS

Philip Bono - An Appreciation

With great regret we record the death on May 23 of Philip Bono, the distinguished aerospace design engineer of Costa Mesa, California. A BIS Fellow of long-standing, Philip was the instigator of novel re-usable launch systems which embodied the principle of vertical take-off and landing (VTOL) examined by McDonnell-Douglas Corporation in the 1960s.

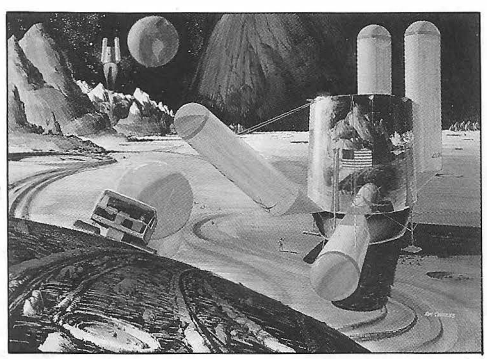
Philip's thesis on rocket travel was consistent over more than a quarter of a century. "No other method of transportation" (he wrote in 1968) "could long survive the extravagance associated with the disposal of the carrier vehicle *after only one use*. Truly efficient space exploration awaits the day when launching can be accomplished by a booster which can be recovered and re-used repeatedly".

In 1967 Philip Bono stands beside a one-sixth scale model of the Pegasus re-usable intercontinental rocket transport.
McDonnell Douglas Space Systems

Bono's vehicles embodied a special type of plug-nozzle engine, regeneratively cooled by LH_2, which upon returning to Earth became a heat shield for the single-stage booster and its integrated pressure cabin. An important attribute of the design was that the vehicle's centre of gravity was kept as far aft as possible to ensure stable flight during re-entry manoeuvres when the vehicle assumed a backward posture. Landing was accomplished tail-first "on the hover" in a manner similar to that of the Apollo lunar module using the plug-nozzle in retro-thrust mode.

Beginning with the Saturn Applications Single-Stage-to-Orbit (SASSTO) vehicle which had a Gemini crew capsule on top of the 14 m tall plug-nozzle engine module, gross mass 90,000 kg, the concept was taken to the ultimate in Rombus, a 6.35 mkg cargo carrier designed to put into close Earth orbit payloads of 362,000 to 453,000 kg.

A full explanation of the various schemes appeared in the book *Frontiers of Space* [1]. Variations of the plug-nozzle boosters were conceived as Pegasus intercontinental rocket transports and vehicles for setting up bases on the Moon and taking astronauts to Mars. So encouraging were these project studies viewed by the National Aeronautics and Space Administration that in 1965 and 1967 two patents were granted to James E. Webb, then NASA administrator, both specifying Philip Bono of Douglas Aircraft Company as the sole inventor. For two seminal engineering papers he received the BIS Golovine Award and the Society of Automotive Engineers' Colwell Merit Award.



Rombus transports begin landing modules of a Moon Base derived from the craft's external tanks.
McDonnell Douglas Space Systems

It is particularly unfortunate that Philip did not live to see the outcome of McDonnell-Douglas's later work on Delta Clipper [2], which his early work inspired.

Sub-scale testing of the single-stage VTOL concept at White Sands Missile Range was due to begin this summer and although Delta Clipper neglects the plug nozzle/heat shield of Bono's patents, re-entering nose-first before executing a swing-over manoeuvre to achieve a thrust-supported landing by conventional rocket engines, the VTOL principle is firmly applied.

With advancing technology, Philip's perceptive ideas may yet provide the solution to building the big re-usable spaceships of the next century... and yet Space and aviation did not occupy all his attention. Philip was above all a caring family man who enjoyed domesticity, auto mechanics and photography. To his wife Camille and their son and two daughters, we extend our deepest sympathy in their sad loss.

References

1. P. Bono and K.W. Gatland, *Frontiers of Space*, Blandford Press, London; Macmillan Publishing Company, New York, 1969; 2nd revised edn 1976.
2. W. Paul Blase, "The First Reusable SSTO Spacecraft", ***Spaceflight***, 35, March 1993.

Kenneth W. Gatland

Launch Report

Third Launch Abort For Discovery

The Launch of STS-51 on 12 August was aborted at T-3 seconds with a harrowing engine shutdown following indications of a problem with the flow rate of fuel into one of the Shuttle's three main engins. The launch had previously been scrubbed twice within eight days, on July 17 and July 24, when the countdowns were within their final minutes.

Above: Rollout of Discovery to Launch Pad 39B on 26 June 1993 (6:50 am) for mission STS-51.

All photos Joel W. Powell/ Space Information Canada

Right: STS-51 crew left to right Culbertson, Readdy, Newman, Bursch and Walz, June 30, 1993.

Engine shutdowns on the pad have only occurred four times previously in the 12-year history of the Shuttle programme. All three main engines appeared to ignite as scheduled at T-6.6 seconds. Almost immediately after the countdown halted, thousands of gallons of water were sprayed on the bottom of the Shuttle and the five astronauts made a hurried exit from the orbiter. The delay until the next launch attempt is expected to last at least a few weeks.

The first launch attempt on July 17 was scrubbed at 8:52 am at the countdown's T-20 minute mark due to a problem with a switch in the Pyrotechnic Initiator Controller which governs the pyrotechnic circuits on the Shuttle. The problem was a prematurely charged capacitor in the firing circuit of all eight solid Rocket Booster holddown bolts and the T-0 liquid hydrogen vent arm. This charge is normally initiated at the T-18 second point.

After safing the Shuttle and launch pad the trouble was traced to a circuit card in the Mobile Launch Platform rather than the Shuttle itself. The problem was duplicated in KSC's malfunction investigtion laboratory and a thermally unstable circuit was found to be the cause.

The flight crew for STS-51; commander Frank Culbertson, pilot Bill Readdy and mission specialists Jim Newman, Dan Bursch and Carl Walz, returned to Houston's Johnson Space Center during the repair efforts. The circuit card was replaced and the next launch attempt was set for Saturday July 24; a week after the initial scrub. The payload bay doors of Discovery were opened and the ACTS/TOS and ORPHEUS payloads were reserviced during this time.

The flight crew returned to KSC and the countdown clock resumed at the T-11 hour mark on Friday July 23 with a T-0 time of 9:27 am on the 24th.

Again, the countdown operations went smoothly. Then, at the T-19 second mark, the countdown was halted by the Shuttle's computers. At that late stage of the countdown activity is controlled by the orbiter computers rather than by the launch crew's computers.

The problem was in the right side Solid Rocket Booster. Steering control of the booster's engine is provided by hydraulic power and the turbine which powers the hydraulic pumps was not coming up to flight speed as it should have. The turbine, which is started at the T-28 second point and burns hydrazine fuel to provide the pump power, should have reached a speed of approximately 70,000 rpm at that point; however, the turbine was about 10,000 rpm slow.

After scrubbing the mission launch crews began the task of investigating the cause. The flight crew again returned to Houston and the payloads were reserviced. ***Roelof L. Schuiling***

Forthcoming Shuttle Launches

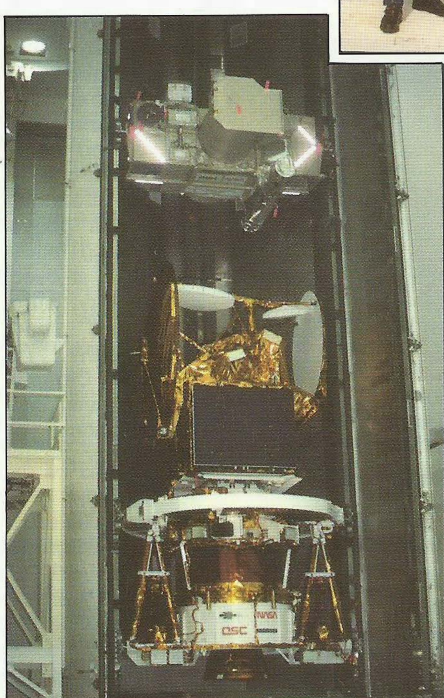
Mission	Launch Target Date	Orbiter Vehicle
STS-51	to be announced	Discovery
STS-58	mid September	Columbia
STS-60	November 10	Discovery
STS-61	December	Endeavour

Sixth Meteosat for Ariane

Five satellites, from Meteosat 2 to Meteosat 6, have been or will be carried into orbit by Ariane launchers between June 1981 and November 1993 for the European Space Agency. ESA subsequently transfers the operation of the spacecraft to the Eumetsat organisation. Meteosat 7 will be directly operated by Eumetsat. It will be placed into a geostationary transfer orbit by an Ariane launch vehicle in late 1995 or early 1996.

The Meteosat 7 spacecraft constitutes the Meteosat Transition Program (MTP) between the end of the Meteosat Operational Program (MOP) in December 1995 and the second-generation Meteosat satellites, scheduled for the year 2000.

The satellite is being built by Aerospatiale, using a MOP platform. It will have a mass at liftoff of about 750 kg.



Left: STS-51 payloads in the transfer canister in the Vertical Processing Facility (VPF) at KSC.

At the top is the ASTRO-SPAS (Shuttle Pallet Satellite) spacecraft which is designed for launch, deployment and retrieval by the space shuttle. It carries the ORFEUS (Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer) telescope which is the large cylinder. The long silver cylinder to the right of it is the IMAPS (Interstellar Medium Absorption Profile Spectrometer). The glowing strips are to aid the new Trajectory Control Sensor (TCS), a laser range-finding devise mounted in the cargo bay, in the rendezvous procedure which is being tested on STS-51.

Below is ACTS-TOS (Advanced Communictions Technology Satellite - Transfer Orbit Stage) which is to provide for the development and flight test of high risk advanced communication satellite technology.

Two Ariane Launches Within a Month

On the night of July 22-23, 1993, Ariane V58 successfully placed into orbit HISPASAT 1B, Spain's second telecommunications satellite, and INSAT 2B, the third Indian multimission satellite to be carried into orbit by the European launch vehicle.

The launch from the Space Center in Kourou, French Guiana, came just 28 days after Flight 57. Europe's Ariane 44L launcher, equipped with four liquid strap-on boosters, lifted off on July 22, 1993 at 07:58:55 sec pm local time.

Provisional parameters at third stage injection into geostationary orbit were:

Perigee: 200.3 km (± 3 km) for a target of 199.7 km
Apogee: 35,957 km (± 120 km) for a target of 35,991 km
Inclination: 6.96° (± 0.06°) for a target of 6.99 degrees.

Hispasat 1B is the second first-generation Hispasat satellite. Prime contractor for the spacecraft was Matra Marconi Space (Toulouse, France). With a mass at liftoff of 2,210 kg, it will provide telecommunications services (voice telephony and data communications) for Spain, the Canary Islands and Latin America.

Insat 2B is the second satellite in the second-generation of the Indian government's Insat programme. The spacecraft was built in Bangalore for the Indian Space Research Organization (ISRO) and will be used to meet India's domestic needs. The multimission satellite, with a mass at liftoff of 1,931 kg, will provide telecommunications, meteorological, search and rescue and educational services.

The next Arianespace launch, Flight 59, will use an Ariane 40 and is scheduled for August 31. It will carry the SPOT 3 Earth Observation satellite, the Stella spatial geodesy satellite for the French Space Agency CNES, and five micro-satellites: Healthsat (USA/GB), Kitsat-B (Korea), Posat-1 (Portugal), Eyesat 1 (USA) and Itamsat (Italy).

Ariane Launch Manifest

Launch	Date	Launcher	Satellites
	1993		
V58	22 July	44L	Hispasat 1B & Insat IIB
V59	31 August	40	Spot 3 + Stella + ASAP No. 4 (*)
V60	October	44LP or 44P	Intelsat VII F1 or Telstar 4
V61	November	44LP	Solidaridad 1 & Mop 3
V62	December	44L	DirecTv 1 & Thaicom 1
	1994		
V63	January	44LP	Eutelsat II F5 & Turksat 1
V64	February	44LP	Intelsat VII F2 or F1
V65	March	44L	Solidaridad II & BS-3N
V66	April	44P or 44L	Telstar 4 or [DirecTv 2 & Thaicom 2]
V67	May	42P	Panamsat 2
V68	June	44LP	Brasilsat B1 & Turksat 2
V69	July	44L or 44LP	[DirecTv 2 & Thaicom 2] or Intelsat VII F2
V70	August/September	42P	Astra 1D
V71	October	44L	Brasilsat B2 & [Eutelsat II F6 or Telecom 2C]
V72	November/December	42P	Panamsat 3 or M-Sat

(*) ASAP No. 4: the fourth Ariane Structure for Auxiliary Payloads, carrying Healthsat, Kitsat-B, Posat-1, Eyesat-1 and Itamsat.
ERS 2 has a contractual priority for a slot from October 1994 onwards.

BAe Support for HISPASAT 1B

British Aerospace has supported Spain's communications satellite programme, HISPASAT, both in manufacture and in launch. The second satellite, HISPASAT 1B was mounted on top of the first Ariane 4 Mini-SPELDA manufactured by British Aerospace (***Spaceflight***, March 1993, p.101). With its payload of the HISPASAT 1B and INSAT 2B spacecraft, Flight 58 was the heaviest dual, or single, Ariane 4 launch to date.

Cosmonaut's Tragic Death

Air Force Major Sergei Vozovikanov was undergoing survival training with two other cosmonauts near Anapa on the Black Sea coast on 21 July 1993. They were fishing in order to learn how to obtain food supplies should their Soyuz space ship come down in an uninhabited area. The major was swept away by a fierce current and became snagged in a fishing net.

He was 35 years old and was selected as a cosmonaut in August 1990, but had not yet been assigned to a particular mission.

Brian Harvey

Mir Missions Until 1996

NPO Energlya of Kaliningrad, with the agreement of RKA (Russian Space Agency), is planning up to six manned Soyuz TM space flights before 1996. It is announcing them, with exact launch dates, to attract potential foreign customers. A $31.2 million contract has been signed with CNES to fly two French cosmonauts on Mir missions in 1993 and 1996. On 7 July 1993, ESA and NPO Energlya signed a contract for Mir precursor flights - the first practical expression of cooperation between ESA and Russia in the field of crewed space flight. The contract is worth 45 million ECU and covers astronaut training, all mission preparations, integration of equipment and experiments to be flown and post-flight follow-up and processing of data. Four ESA astronauts, Pedro Duque, Christer Fuglesang, Ulf Merbold and Thomas Reiter, will be training at Star City near Moscow. (See *Spaceflight*, July 1993, p.237)

Operations with the Mir complex are planned as follows (Progress launches are mentioned only for 1993):

1 July: Soyuz TM-17 has recently been launched to the Mir space station for the French-Russian "Altaïr" mission.

21 July: Progress M-19 launched to resupply Mir with food, propellant and materials.

12 October: Progress M-20 launch in order to prepare for the next manned mission aboard Mir.

24 November: mission 15 with lift-off of Soyuz TM-18 and a three-man crew consisting of cosmonauts Yuri Malenchenko and Alexander Kaleri, accompanied by a doctor-cosmonaut, who is trained to break the duration record in space with a stay of 16 months, until March 1995.

25 April 1994: mission 16 with Soyuz TM-19 and a crew consisting of cosmonauts Viktor Afanassiev and Yuri Ussachov; a Canadian astronaut would be welcome to participate to this mission.

17 September: mission 17 with Soyuz TM-20; an ESA astronaut (Pedro Duque of Spain, Ulf Merbold of Germany) would be a member of the three-person crew for a 30-day space flight; Yelena Kondakova - the wife of cosmonaut Valeri Riumin who spent a total of 360 days in space during two missions in the Salyut 6 station - could remain on Mir for a 6-month mission.

1 March 1995: mission 18 of Soyuz TM-21 with a crew of one NASA astronaut who will remain in orbit for 90 days until May 1995. The Russian doctor and Yelena Kondakova will come back after flights of respectively some 16 months and 6 months.

3 June 1995: Space Shuttle Atlantis docking with the Kristall port of the Mir complex for a one-week joint space flight; it will bring back the American astronaut.

8 August: mission 19 with Soyuz TM-22; an ESA astronaut would undertake a long-duration mission of 135 days.

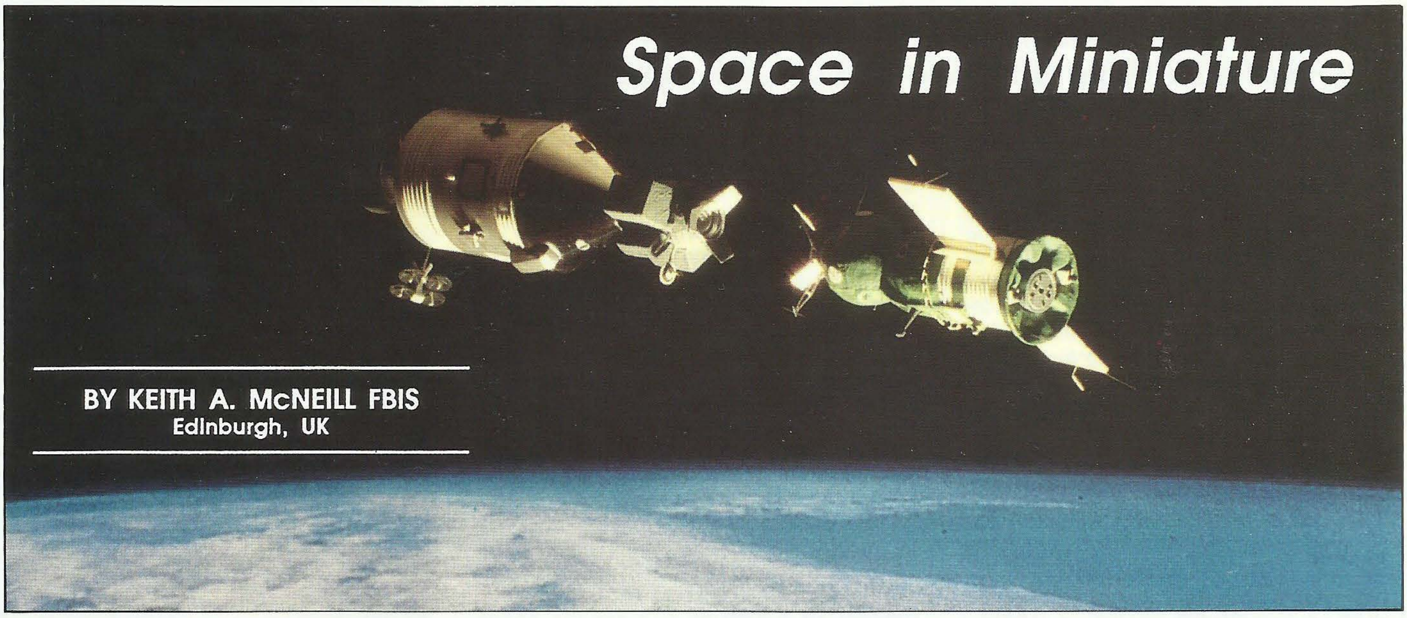
January 1996: Soyuz TM-23 launched to Mir for the French-Russian "Cassiopea" mission with a crew consisting of two Russian cosmonauts and the French cosmonaut Claudie Andre-Deshays. This crew appears to be the last one that will visit the Mir-1 station.

The immediate problem for RKA (Russian Space Agency) and NPO Energiya is to keep the Mir complex alive until late 1995 for the docking with Atlantis.

Theo Pirard

(See Mir Mission Report - p.317).

Space in Miniature



BY KEITH A. McNEILL FBIS
Edinburgh, UK

Apollo and Soyuz about to dock above the Earth. *(c) Keith McNeill 1993*

"I have been building spacecraft models for nearly twenty-five years and I have also developed a hobby of photographing these models", says Keith McNeill, a long-standing Fellow of the Society. In this article he writes about his hobby with ready advice on his 'speciality' of photographing models in realistic settings.

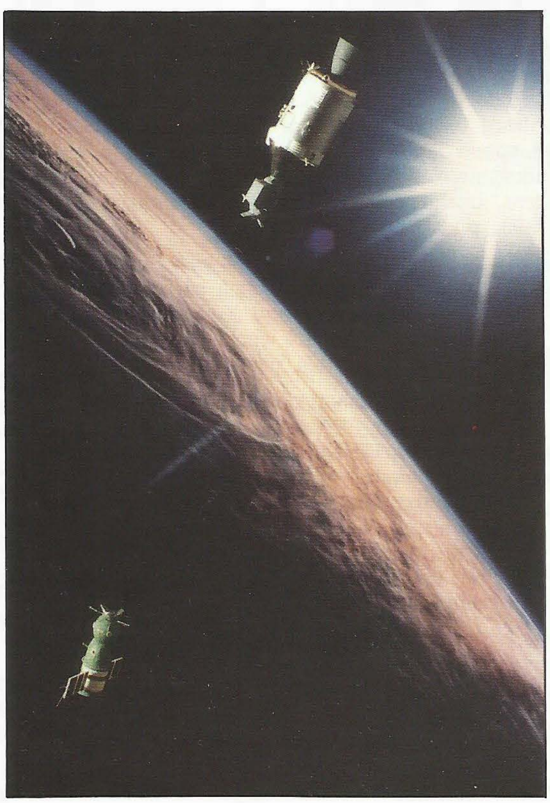
Like most people of my age I watched with fascination the early Gerry Anderson series such as Fireball XL5 and Thunderbirds. Since then I have remained fascinated by special effects used in the film industry. Early on my friend Jeff Hosea and I decided to try and emulate some of those model shots on still film. Neither of us had any knowledge of photography, and our early attempts were based purely on trial and error. As such, we tried taking photographs of balsa models using only a Kodak Brownie camera outdoors. Knowing nothing of things such as Depth of Field and exposure times, we got reasonable results more by luck than judgement.

Years later when both of us had become space enthusiasts we decided to update our equipment and learn something more about photography. As a result a small 35 mm camera was purchased from Boots the Chemist and a 250 W Photoflood bulb acquired. As the Apollo missions were at their height at that time, what better than to photograph some of the Apollo models which were then generally available?

Despite consulting camera shop assistants, we were unable to come to any conclusions as what way was best to carry out our aim. This was certainly not the type of questions on "normal" photography they were used to !! After much experimentation we settled on a Kodak transparency film with a speed of 100 ASA. In the early seventies there was no fast print film, and although we both prefer prints we had no choice but to accept slides. However, the slide film used was balanced for Photofloods and no filter was needed. It was at this time that we developed our methods for space model photography, which with some modifications is the method I still use to this day.

I will give a brief description of the equipment I am currently using followed by a resume of the method of photographing space models in their simulated "natural environment". My camera is a Minolta X700 SLR which with a bit of care can take double exposures. This is an important aspect of my technique. When I went shopping for a decent SLR I was amazed at how difficult it was to obtain a camera which is able to do such a thing. Admittedly this is not usually something you would want to do. A Single Lens Reflex camera is necessary, as with the close-up work involved with this type of photography, parallax comes into play. This occurs when an object is so close to the camera that the lens on a normal camera does not see what the viewfinder does. Admittedly there are ways around this, but things start to get quite complicated. The film I use is Kodak Gold 200 ASA print film. For illumination I employ a 500 W Photoflood bulb mounted in an old anglepoise lamp (as these are only meant to take 60 W household bulbs, care has to be taken to ensure no overheating). As the film used is a daylight one, an 80B filter is required for colour correction. Long exposures are often needed for this type of photography, so obviously a tripod and cable release are essential. To simulate the blackness of space, a large background of black velvet is required. Even if stray light falls onto this, there is little likelihood of this being registered on the film.

Apollo and Soyuz about to dock with Earth and Sun in background. *(c) Keith McNeill 1993*



Originally we had access to a very large old attic and we suspended an old bedstead from the rafters, attached to which was a wooden frame with black cloth stretched between. The idea was to suspend the model from threads which went through the background and were tied off on the lattice of bedsprings. The camera was then located under the model pointing

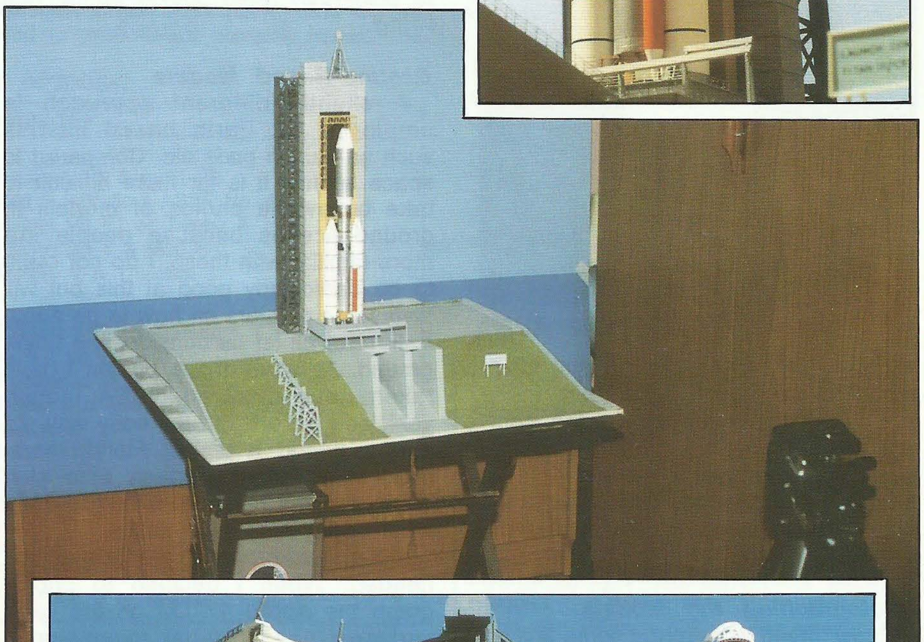
upwards. In this way the model itself would obscure the threads. Only years later did I discover that this method is sometimes used in the film business. Unfortunately I do not have room for this type of set up anymore and therefore have had to devise an alternative. I suspend the model in front of the background, but upside down. The model is then lit from below and the resulting shadow obliterates the threads (usually). The only disadvantage to this is that you have to compose the photo upside down - but then there is no right way up in space.

As mentioned earlier I use a 500 W Photoflood. In space the illumination is very directional. Therefore a snout or spot has to be used. This is made from kitchen foil which will resist the heat build-up without catching fire. This also keeps unwelcome light from falling onto the threads.

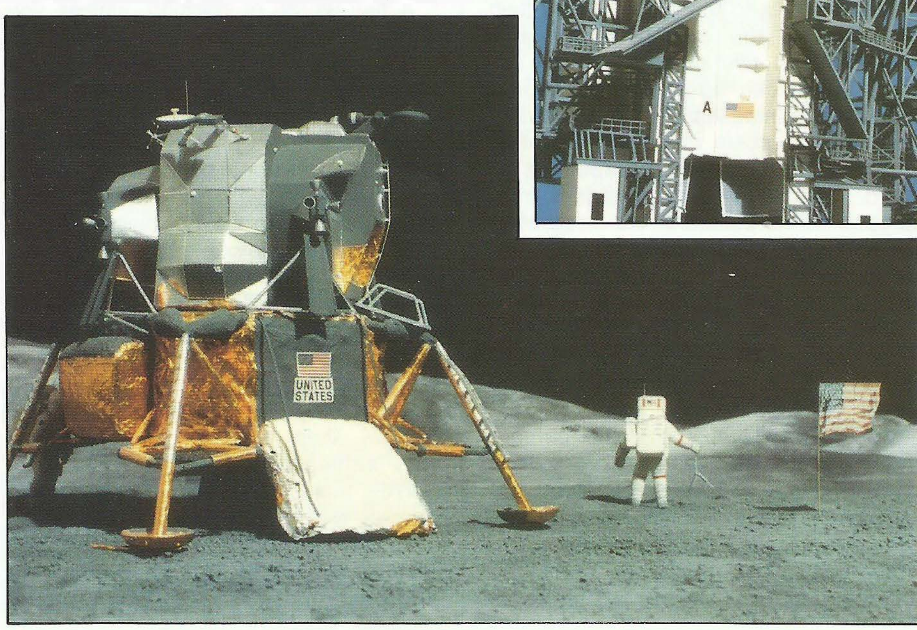
I mentioned previously the necessity of purchasing a camera with a double exposure facility. Although the photography of space models suspended against the blackness of space can be most satisfying, more interesting photographs can be obtained by placing the spacecraft in the vicinity of planets such as the Earth or Moon. This is achieved by double exposing a slide of the required planet onto the photo of the model. Over the years I have acquired many slides from both the Apollo and shuttle missions and these have been used for a dual purpose - both as a collection of space flight images and also for my photographic purposes. Obviously the model can only be positioned in the black areas of the slide because it would take on a ghostly appearance if it were superimposed on a bright object such as a planet. A slide duplicator, which is mounted on the camera body in place of the lens, can be obtained from most photographic shops. All that is necessary is to then point the camera at a light source and expose the frame. I have found that natural daylight gives the best colour rendition, although if there is a clear blue sky you may get a slight bluish tinge.

Every camera is no doubt different, but to achieve a double exposure with the Minolta, after loading the film, the rewind spool should be wound back to take up any slack of film in the canister. Then, whilst holding the rewind spool tight, depress and hold down the release button on the bottom of the camera and carefully wind on. If this is done slowly, the film should not move inside the camera. Basically, you have fooled the camera into thinking that the next frame has been wound into position!

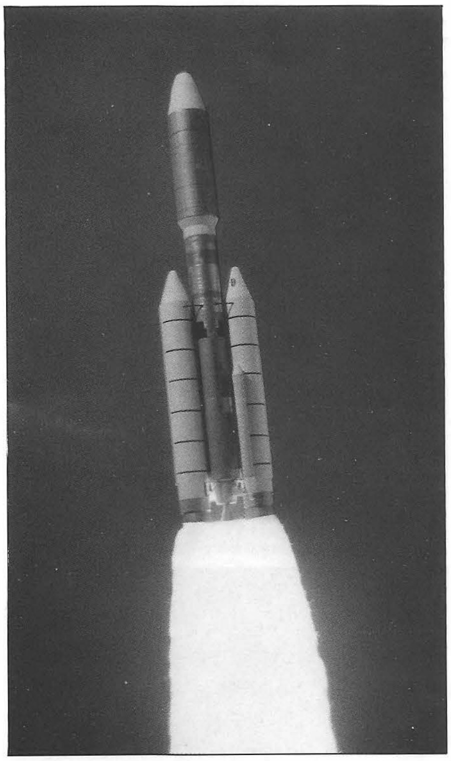
Right: Titan III with scratchbuilt Launch Tower.
Below: Setup. for Titan model photograhpy.
photos (c) Keith McNeill 1992



Above: Shuttle Launch Tower, 1:144.
(c) Keith McNeill 1988
Left Apollo 17 Lunar Module.
(c) Keith McNeill 1992



To obtain the greatest Depth of Field (the distance over which everything in the image is in focus) f22 is used. With a 500 W Photoflood positioned a mere three to four feet away, a two second



Titan III launch. *(c) Keith McNeill 1992*

exposure is necessary. Virtually every model photograph I take uses these settings. The electronics in the camera often indicate a different exposure, but whenever I have taken the advice of the camera, the photographs have always been slightly under-exposed.

Photographing the Models

I now intend to describe some tips on how to make models look reasonably realistic. Space is the natural environment one must simulate. As mentioned previously, merely double-exposing a planet into the image improves the photograph immensely. However some care has to be taken with choosing the right slide to use. Unfortunately this is a combination of luck and experience. Basically one should try to match the colour cast, sharpness and contrast of the planet with what the model will end up looking like in the image. Thus the model should blend in and not appear as if it has been stuck on to the original photo of the planet.

Also if the spacecraft has a very reflective surface (such as on the Apollo Command Module), care should be taken to ensure no extraneous reflection such as furniture in the room! This can be achieved by strategically placing black or white card around the model (but out of camera view obviously).

The spacecraft can be viewed from any angle, but I find that photographing them from angles and in surroundings in which the real spacecraft are normally seen adds a touch of realism. The eye and mind automatically relate to previously seen photos of the real thing.

Ground-Based Models

A slightly different approach is employed for Earth based models such as launch pads etc. Compared to space scenes it is far more difficult to take believable photos of models in ground scenes because people are more familiar with these. I do not claim to be particularly good at this but will give some pointers on how to go about it. First of all let us consider the background. As most of the photos I have taken have involved NASA launch vehicles I have taken the easy way out and assumed a typical Florida summer. Hence an unbroken blue sky. Therefore any reasonable mid to deep blue background will suffice.

Other backgrounds are sometimes needed. When I decided to photograph the Apollo 17 LM on the lunar surface I needed lunar mountains. I chose a good photograph (coincidently of the Apollo 17 landing site mountains at Taurus-Littrow). Colour photocopies were taken and these were made into a mosaic. Incidentally, model figures do not usually look convincing and can detract from the overall effect. One way round this is to cut out a photograph of a real person (in this case an Apollo astronaut on the Moon) and stand the cutout in the field of view. As the camera lens views everything in two dimensions the finished result can be quite effective. As it is usually impossible to find a cutout to the same scale of the model being photographed, forced perspective is used. This is where an object of a larger scale is placed in the foreground (or one of a small scale placed in the background), giving the effect of greater distance. This is also used where depth of field is at a premium. Two items might only be inches away but in the photograph appear to be some distance apart.

For ground-level shots, the camera must get as low as possible to the miniature set. In theory what you are aiming for is the eyelevel of a person of the same scale as the model. Obviously this is not attainable, but if the camera lens is at as low an angle as possible, looking up at the model, the launch vehicle instantly looks large. I have taken photographs of the shuttle, Titan III, Mercury Atlas and Buran launch pads using this method.

Until recently I have not been able to take photographs of launch vehicles simulated in flight due to the difficulty in reproducing the bright exhaust. However I have recently solved this problem. First the launch vehicle is mounted on wire rods which are inserted into a block of polystyrene. Ordinary cotton wool is then sculpted around the wire in the shape of the exhaust, keeping the wool as thin as possible without revealing the wire rods. A vertical fluorescent tube is placed behind (and hidden by) the cotton wool. When lit, the cotton wool should glow brightly so that the rods are not visible.

The photographic procedure required is as follows. First of all the blue background is covered with the black velvet background. A black hood is placed over the camera and the fluorescent tube switched on. Using the cable release, the lens is opened. The lowest possible f-stop is used (on my camera f1.7). The hood is then withdrawn from the lens and an exposure taken. I have found by trial and error that 60 to 90 seconds proves effective. Once the exposure has been completed, the hood is replaced over the lens. The velvet is then removed from the sky background, and the normal 500 W Photoflood is switched on. Meanwhile the aperture should be changed to f22(carefully, so as not to disturb the camera. Remember the lens is still open). Finally the black hood is once again withdrawn from the lens and the model exposed for two seconds before releasing the cable release. The end result being the lift-off of a launch vehicle with a bright exhaust plume.

The End Product

A few words of warning. Unless you intend developing your own colour film (I do not), you will find commercial labs are not accustomed to this type of photography (especially the shots with a lot of black space). They are geared to normal snap-shot photography, and the machines will generally overexpose photos with a lot of black in them. You will end up with grossly over exposed white "blobs" in a sea of grey (or blue, green or brown depending on the colour settings of the machine). I have found that if you specify the type of photographs contained in the film and ask that they print the background JET BLACK, then you will usually receive very satisfactory results.

Well, there you have it. I hope I have proved that anyone with fairly standard SLR equipment can obtain the results shown in the accompanying photographs.

Teachers: Model Making Booklet

The Society is in the process of updating the 'Model Making in Astronautics' booklet issued for schools some years ago for children in the 9-14 age group.

It would help us to identify more closely the kind of material required if teachers and others interested in educational activities could send us their comments on model making suitable for the classroom.

Please send your suggestions to:
Mr L.J. Carter, Special Projects Officer, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Launch of STS-57 from Pad 39B as photographed from the press site with a 500 mm lens. *Joel W. Powell/Space Information Canada*

Spacehab Debut: Eureca Retrieval

Roelof L. Schuiling provides a first-hand account of the preparations and launch of STS-57, for which he served as NASA Payload Manager. The article concludes with a day-by-day account of the activities of the astronauts during the orbital mission. He writes:

At 9:07 am plus 23 seconds on June 21, 1993 those of us in the Kennedy Space Center's Launch Control Center firing rooms watched the Shuttle Endeavour breaking free from its launch pad. There was no applause at the liftoff - that came at the Solid Rocket Booster's separation 2 minutes and 5 seconds into the flight when the launch crews knew that the astronauts had a good chance to recover from any subsequent engine failure.

At the Launch

Before solid motor burnout, a booster failure means little chance of a safe emergency landing. It is a long 2 minutes - it always is. By contrast, during the next six and a half minutes until the main engines shut down we could uncross our fingers just a little bit and follow the ascent. Engine failures would mean an abort but only a catastrophic engine failure would remove the possibility of an emergency landing.

After the Shuttle clears the launch tower, control of the launch activity passes to Johnson Space Center in Houston and we could follow the communications between Houston and Endeavour. We could hear the flight controller call "Endeavour - negative return" meaning that the Kennedy Space Center would not be the emergency landing point if a failure occurred further in the ascent. A transatlantic landing site at Banjul in Africa would be the prime abort landing site. In a few minutes we heard the controller call "Abort-to-orbit" as the primary abort choice. In Abort-to-orbit the Shuttle does not abort to an Earth landing but reaches a less desirable than planned orbit of about 105 nautical miles. This allows the crew and the flight controllers time to deal with whatever caused the failure and develop plans to get the orbiter back on the ground safely without the immediate need to land.

For me, reaching the abort-to-orbit point has a special significance. An airliner is standing by at launch ready to come to KSC in order to take a crew of personnel to a "contingency" landing site if the orbiter makes an emergency abort landing. The Payload Manager is one of three payload workers who have to board the plane and leave within six hours. I attend my launches with a packed suitcase, but on the morning of June 21 the last place in which I wanted to have evening dinner was a transatlantic abort site in Africa.

Getting Started

The STS-57 launch came after years of preparation throughout the NASA space programme. My first involvement with the mission and its payloads had been in the summer of 1990. I had just served as NASA Payload Manager on the STS-34 Galileo and STS-32 Syncom/LDEF-retrieval missions and I was actively engaged in preparations for my next mission which was STS-39. Following STS-39 I would have STS-48, STS-49, STS-53 and STS-54 payloads to launch before the arrival of the STS-57 payloads.

In mid-summer 1990 our mission planning included the first Spacehab module and the Superfluid Helium On-Orbit Transfer (SHOOT) payloads with a tentative launch date estimate of September, 1992 and a mission designation of STS-55 later to be changed to STS-57. Both payloads had some interesting characteristics.

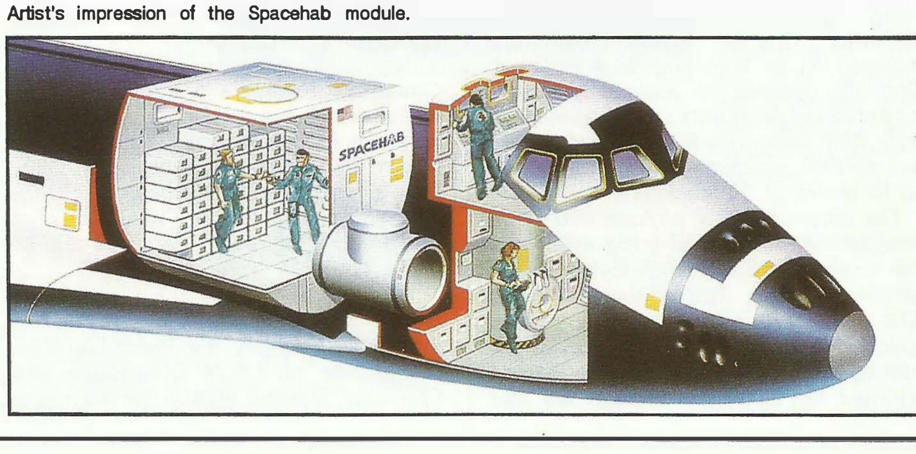
Spacehab

Spacehab was a pressurised module attached to the orbiter middeck by a short pressurised passage. The passage included a hatch which opened into the payload bay for astronaut EVA operations. The 9 foot long module carried experiments in locker-type drawers on its forward and aft bulkheads. These lockers are similar to those in the Shuttle middeck which allow astronauts to conduct "hands on" experiments during flight.

Spacehab could also carry larger experiments in racks along either wall. The great advantage of Spacehab was that it would allow more of these smaller experiments from research laboratories to be carried in one flight than could be carried in several Shuttle flights using middeck lockers alone. In typical bureaucratese the government referred to the programme as the "Commercial Middeck Augmentation Module".

Eventually STS-57 was to carry over 20 different experiments as part of the Spacehab flight. Spacehab is a commercially developed programme which rents its experiment space to customers somewhat like an astronautical hotel keeper. As with terrestrial hotels, it provides electrical power, heating, cooling and communications services - it even has a tiny window with a magnificent view!

Artist's impression of the Spacehab module.



SHOOT

SHOOT was a payload to study the use of superfluid helium in space. Helium is an excellent heat remover and its use is vital for astronomical instruments which must be kept cooled to a very low temperature. Superfluid helium is cooled to only about 2 degrees above absolute zero - a region in which it experiences no viscosity. The understanding of superfluid helium characteristics in space will permit more efficient cooling of instruments on-orbit than is possible with normal liquid helium. SHOOT consisted of two helium dewar tanks (a sort of large insulated thermos) mounted on a cross-bay trusswork structure termed a Mission Peculiar Equipment Support Structure. Of course no one ever really called it that as it was always referred to as an MPESS (pronounced "Em'pess"). These MPESS units are the workhorses of the Shuttle payload programmes and they are used to carry many other types of payload.

SHOOT was developed and managed by NASA's Goddard Space Flight Center in Maryland. It was part of a programme they call "Hitchhiker" which flies on many Shuttle missions. Over the next few years meetings at KSC, Huntsville and Houston coordinated our planning for the payload's prelaunch operations. During our meetings a major discussion subject for the Spacehab was late access stowage of experiments, specimens and samples, but SHOOT had its own major late service characteristic in that the cryogenic liquid helium supplies had to be topped off as close to the launch as possible in order to have enough helium on-orbit to complete its programme of studies.

Unlike Spacehab, there was no way that we could reach SHOOT through the cabin. That meant that our final service with liquid helium had to be done just prior to closing the payload bay doors. Since the payload bay doors must be closed during the early stages of the countdown, much of my operational planning for SHOOT involved trying to get as late a service time as possible.

Payloads: Up and Down!

By the summer of 1992 the mission was scheduled for July of 1993 and it had taken on its final designation of STS-57. The orbiter Endeavour was to be our launch vehicle. We also had two additions to our complement of cargoes.

At the rear end of the Endeavour's payload bay the mission planners had incorporated a GAS Bridge Assembly (GBA), which is another MPESS but with Getaway Special (GAS) canisters mounted on its front and back structure. Originally planned as payload bay wall-mounted experiments, GAS canisters were now being regularly flown on cross bay MPESS structures which could carry up to twelve of the canisters.

The other additional payload was to be coming down, instead of going up. It was the European Space Agency's Eureca satellite. Eureca was deployed by the STS-46 mission, spent almost a year in space doing materials microgravity research, and was now to be retrieved and returned on STS-57. Although we had little prelaunch planning for Eureca, there was much to plan for the landing. Eureca would be retrieved with several hundred pounds of residual toxic hydrazine propellant and safety concerns had to be addressed and contingency plans developed to deal with the possibility of a leak during the landing or the unloading of the payloads. In addition, Eureca had many delicate samples resulting from its experimental work and these samples had to be removed from Eureca as soon as the payload bay doors could be opened on the ground - even sooner than removing the Eureca itself from the orbiter.

About the Crew

The STS-57 crew included veteran astronaut Ronald J. Grabe, 47, Col., USAF, as mission commander. STS-57 was his fourth space flight as he had served as pilot on STS-51J and STS-30 as well as commander on STS-42. The mission's pilot was Brian Duffy, 39, Col., USAF. Duffy had previously flown once on STS-45.

G. David Low, 37, served as payload commander and mission specialist number one on STS-57. Low had previously flown on STS-32 and STS-43. Mission specialist number two was Nancy Jane Sherlock, 34, Capt., USA, who was making her first flight. Also making their first flights on STS-57 were Peter J.K. (Jeff) Wisoff, 34, as mission specialist number three and Janice Voss, 36, as mission specialist number four.

The Team Comes Together

By late 1992, when I was in the last phases of my STS-54 prelaunch activities with the TDRS satellite and X-ray spectrometer payloads, our STS-57 test team was coming into its final form. Officially it was the KSC Payload Mission Processing Team; however, we just referred to it as the "Test Team". Joining our systems engineering and operation personnel were security, quality assurance, safety, communications, environmental health, Shuttle operations and Shuttle integration team members. Not the least were representatives from the payload developers - our Shuttle customers - themselves. The meetings of the team were weekly until shortly before the first payload arrived, then daily until after the landing when the payloads had been removed from the Endeavour, bundled up and then sent back to their fond parents and experimenters. As Payload Manager, I co-chaired the meeting with my contractor counterparts, McDonnell Douglas, who is NASA's payload support contractor and provides about half of the test team's personnel.

Also in late 1992 was the KSC Ground Operations Review - a formal presentation in which we presented our planning to prove to our superiors that the team was ready to receive the payloads. Other than a request from Spacehab to change their arrival date slightly - which we were able to do - the review went well and no major concerns were surfaced.

Spacehab Checkout

Early in February the Spacehab module arrived at KSC's Operations and Checkout building (O&C) for its major prelaunch testing which involved installing the Spacehab module in a test stand which simulates the orbiter payload bay dimensions and the orbiter's electrical and avionic systems as well. The operations in this stand, which is called the Cargo Interface Test Stand (or CITE; pronounced "site"), make sure that all of the payload's connections with the orbiter will (in space-talk) "interface" correctly before we install the payload in the orbiter.

By checking our payloads with this "simulated Shuttle" we can find the problems and fix them before we install the payload in the real Shuttle orbiter. Shuttle processing time is expensive and, also, delays in an orbiter's prelaunch processing would affect the prelaunch processing of the other Shuttle missions. What we did not need was a delay in the Shuttle schedule while we chased down problems in the payload.

With the arrival of the payloads at KSC our test team meetings had become daily. Each afternoon at 2:00 pm we checked on the progress of the day's activities and made sure that the next day's operations were on schedule. Planning for the next few weeks was also reviewed and the Shuttle orbiter's progress was checked to insure that our schedules and the orbiter's schedules were tracking together. These meetings continued throughout the STS-57 prelaunch, mission and unloading operations.

SHOOT Checkout

Also in February, the SHOOT payload arrived at KSC. It spent several weeks in final preparation for test operations. SHOOT had been loaded with helium at the Goddard Space Flight Center before it was shipped to KSC and it was periodically topped-off with helium while it was here at the launch centre.

Late in February SHOOT arrived at KSC's Vertical Processing Facility (VPF - and there is no way to pronounce VPF except VPF) for its own CITE testing, which went well - actually better than well as we solved a problem we had seen on other Hitchhiker programme payloads.

Installing Payloads

Payloads at KSC may be loaded into the Shuttle orbiter either at the Orbiter Processing Facility (OPF) or at a launch pad. The OPF is the orbiter's main work and preparation location. The OPF is like an airplane's "hangar", but it is only for Shuttles. An orbiter is horizontal when in the OPF and vertical when at the launch pad. Therefore, payloads loaded at the OPF are called "horizontal payloads" (e.g. Spacehab) while those loaded at the pad are called "vertical payloads" (e.g. SHOOT). Hence the term Vertical Processing Facility.

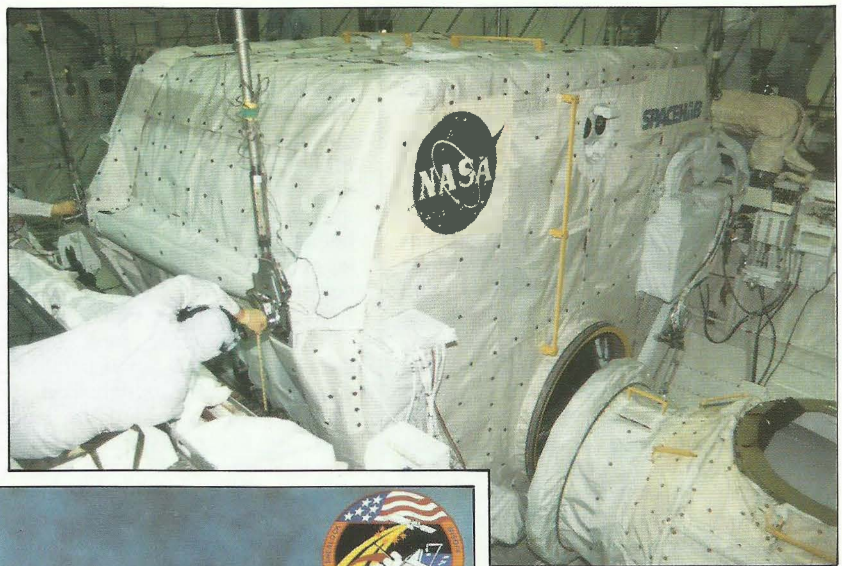
At the VPF

At the VPF the payloads are in the same vertical orientation as they will be at the pad. If several of the mission's payloads are "vertical payloads" they will be positioned one over another in the VPF's work stand. They will be separated by the same distance as in the Shuttle orbiter, their

connecting cables will be in the same relation as in the orbiter and they will be transported to the launch pad for installation in the orbiter in that same relation.

At the OPF

The GAS Bridge Assembly completed its preparations and arrived at the O&C in late February. There it met the Spacehab and they were installed together into a "transfer canister" for delivery to the orbiter at the OPF. As with the "vertical payloads", the "horizontal payloads" en route to the OPF are installed into the transfer canister in the same locations and using the same type fittings as in the actual orbiter.



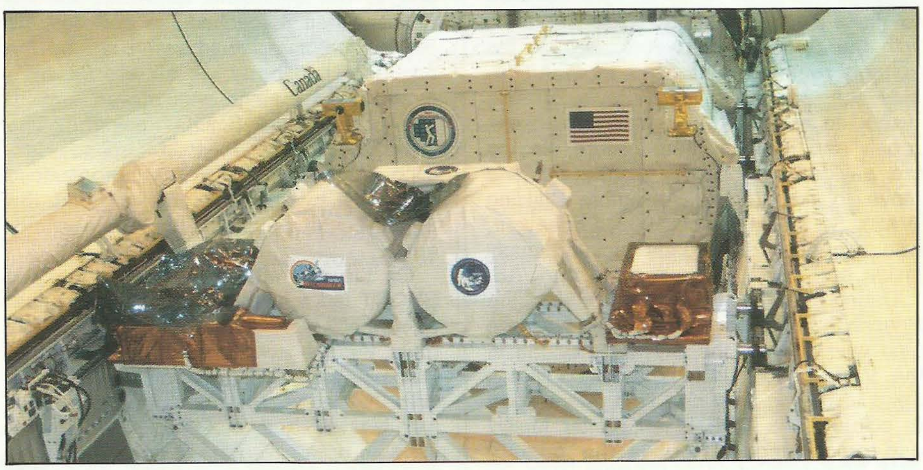
Above: The Spacehab module is being transferred from the canister transporter into the payload bay of the orbiter during preflight processing in the OPF. *NASA*

The Transfer Canister

The transfer canister is a huge container which is the size and shape of a wingless Shuttle orbiter from the aft cabin wall to the end of the payload bay. It even has doors along its back similar to those of the orbiter.

The transfer canister with its payload cargo is moved by roadway (not during rush hour traffic, however, as it closes down KSC's major roadways during the moves) to the Shuttle orbiter - either at the OPF or, in the case of "vertical payloads", at the launch pad. On its drive to the OPF it is horizontal, but on the drive to the launch pad it is rotated to a vertical position so as to match the orbiter. The canister rides on a large special flatbed transporter.

Left: The STS-57 crew from left to right: Wisoff, Duffy, Sherlock, Voss, Grabe and Low. *NASA*



Below: Inside the cargo bay at Launch Pad 39B are the Spacehab Laboratory module (upper) and the Super Fluid Helium On Orbit Transfer (SHOOT). *NASA*

Launch Delays

As the payloads for STS-57 arrived and began to undergo their processing, we were working toward a launch date of April 28. I began to cast a wary eye on the fortunes of the STS-55 and STS-56 missions of my fellow Payload Managers (there are four of us). Both of these had been scheduled to launch ahead of us.

STS-55 with the Spacelab-D2 aboard Columbia had been set for February 25, but an issue had arisen as to the correct seals in the main engine turbopumps. The pumps on Columbia had to be replaced to insure that the correct seals would be used and the old pumps inspected. As it turned out the correct seals had been installed and only the paperwork was at issue; however this delayed the STS-55 mission, which delayed the STS-56 mission, which delayed my STS-57 mission.

Since a concern had surfaced about the pump seals in Columbia a similar concern arose about the seals in Discovery's engines. In Discovery's case, Shuttle programme managers decided it would be easier to just replace the engines as she was still in the OPF and it would be easier to simply replace the engines with new engines having pumps which had been inspected to insure the right seals. Columbia was already at the launch pad with engines so it was easier to just replace the pumps.

But where was Discovery to get its new engines? There are only about three dozen engines in the programme and they are in constant preparation for flight, inspection and post flight status. There is no warehouse filled with spare Shuttle engines. So where to look for engines? Unfortunately for us on STS-57, Discovery got its new engines from Endeavour. There is always the matter of priorities and the next Shuttle to launch gets the higher priority in personnel, crane use, test scheduling, support - and, of course in engines. At this time Endeavour was number three in line to launch behind Discovery. Although the KSC STS-57 team offered to jump to the head of the queue we were not accepted!

Shortly after this we watched as Columbia's STS-55 mission experienced an engine shutdown only seconds before its scheduled launch on March 22. Discovery now with "our" engines, vaulted into the next launch position in early April. Although Endeavour's KSC team offered to "play through" and launch in late April ahead of Columbia such was not to be. We found we were now scheduled for a late May or early June launch.

Trouble Shooting

During Columbia's tribulations we proceeded with our own STS-57 payload processing work. Spacehab and the GAS Bridge were loaded into the transfer canister and taken to the OPF where they were installed in Endeavour on March 4. The connecting pressurised passage

from the crew cabin to the Spacehab module had previously been installed in the orbiter. As we were completing checks and the avionic and electrical connections between the payloads and the orbiter we were notified that in another space programme a suspect voltage regulator had been detected in the avionics.

As Spacehab had the same type of component, the decision was made to remove the units in which the regulator was used and replace the component. This was not an easy task as we were by then only about six days away from closing the Spacehab module's hatch in preparation for the move to the launch pad and much remained to be done. A technician was flown in to remove the unit on a Friday and we were able to schedule operations over the weekend. The technician was then able to get the unit back to us by Monday evening.

During that weekend we had the flight crew astronauts in from Houston to check out the interior and exterior of the payloads. This would be their last opportunity to be inside Spacehab since it would be in a vertical position at the launch pad when the hatches leading to its interior were next opened. We checked the pressurisation of the combined Shuttle cabin and Spacehab module by pressurising them and then tracking the decay over about a day to make sure that there were no pressure leaks.

During these operations we also found that several of the insulation blankets on Spacehab did not have enough electrical bonding between their layers. These blankets had to be removed and reworked to make sure of a good electrical bond with the Spacehab structure. So, as the voltage regulator unit was replaced inside the Spacehab, the crews outside rushed to remove the insulation blankets, repair and replace them before closing the payload bay doors for the orbiter's move to the Vehicle Assembly Building (VAB). So on 24 March 1993, Endeavour, with two of our payloads tucked snugly inside her, made the journey to the VAB.

During the time we were working the Spacehab operations in the OPF, we were also working with the SHOOT payload in the VPF - two buildings twenty minutes apart in driving time and light years apart in culture. The OPF is an orbiter facility and processing orbiters is the primary goal and a multitude of orbiter systems forms the working backdrop, while the VPF is entirely dominated by the payload world and payload processing is king. It was probably a tossup as to who was happier when Endeavour rolled to the VAB - the payloads team who could forget about OPF operations until unloading their payloads after landing - or the OPF crews who had the payloaders successfully out of their hair for a while!

SHOOT Moves to Pad 39B

Immediately after STS-56's launch on April 8 we began preparations to bring SHOOT to the launch pad. The same transfer canister which had transported Spacehab and GAS Bridge to the OPF was rotated 90 degrees so that it sat upon its end on its transporter. Now 65 feet high, the upright canister was moved into the VPF, its doors were opened, and it was moved up to the SHOOT payload. The SHOOT payload was moved into the canister, just as it would be moved into the orbiter, by translating the work stand's support structure forward. After closing the canister's doors the transfer canister began its journey - still vertical - to the launch pad. The move of the vertical canister was set for the late evening of April 15 after peak traffic hours.

The transporter took the canister through the KSC administrative and industrial area with its darkened shops and offices, then up toward the launch complex. As the canister moves along the four-lane highway its great size is emphasised by how small the escort automobiles in front of, and behind it appear. You cannot help thinking how huge the Shuttle would look in the same relation since the canister is basically a Shuttle orbiter midbody. If you added wings, tail and crew cabin you would have almost the same shape as an orbiter.

The route passed by the VAB and the Launch Control Center and then paralleled the Shuttle's crawlerway to Launch Complex 39B. Early on the morning of the 16th, after a fourteen mile trip, the canister arrived at the base of the pad 39B service structure. The structure was rotated away from the spot the orbiter would eventually reach and the canister was hoisted up to the protective enclosure that would surround the orbiter's upper midbody.

The canister was now in the same relation to the enclosure as would be the Shuttle when it reached the pad and the service structure would swing around the orbiter's mid-body. A six-storey high movable work stand was moved forward and grasped the SHOOT payload. The stand, called the Payload Ground Handling Mechanism, or PGHM (pronounced "pig'ehm" by the workers) grasped the SHOOT and pulled it inside the enclosure.

On the day after its arrival at the pad SHOOT did a functional test to insure that all was still well. We stood down for a few days for the countdown and launch of Columbia's STS-55 mission on 26 April from the adjacent Launch Complex 39A just two miles away. For launch operations an area called the Blast Danger area is cleared of non-essential personnel. This extends about three miles from the launch pads back almost to the Launch Control Center and it includes the adjacent Shuttle launch pad.

Endeavour at Pad 39B

Endeavour, now in the VAB, began engine installation on April 16 and completed all of the installations and leak checks by the 27th. After STS-55's launch, Endeavour rolled out to the launch pad on the 28th.

In addition to our daily afternoon payload team meeting the entire STS-57 Shuttle launch team began to meet each morning at the Launch Control Center's conference room, now that the STS-57 Shuttle complement was at the launch pad. After going over the mission prelaunch status and planning, each system and subsystem was queried as to its concerns. One really gets an idea of the extent of the complexity of this operation as you hear called on:

> LOX, LH2, External Tank SRB Electrical, Launch Pad Electrical, External Tank Mechanical, SRB Mechanical, Shuttle Hydraulics, Orbiter Electrical, Instrumentation, Hazardous Gas Detection, Communications Systems, Pyrotechnics, Data Processing, Flight Software, Orbital Manoeuvring/Reaction Control, Auxiliary Power, Environmental Control, Fuel Cells, Main Propulsion Systems, Main Propulsion Engines, Rocketdyne (engine builder), Shuttle Structures & Mechanisms, Pad Hydraulics, Thermal Protection (tiles), Umbilicals, Swing Arms, Ground Support Equipment, Orbiter Payload Integration, Payload Processing *(that was us)*, Flow Management, Shop Support, Launch Pad, Work Control, Quality Control, Orbiter Planning Forward Area, Orbiter Planning Aft Area, Launch Control Center, Safety, Test Support, Launch Processing (launch computers) System, Base Support, Logistics, NASA Project Engineering, Lockheed Project Engineering, Rockwell (orbiter manufacturer), Integrated Flow Operations, Orbiter Manager, Test Director and Flow Director.

All in all, it is quite impressive to hear all the areas and systems involved.

After Endeavour had arrived at Launch Complex 39B the service structure rotated the payload enclosure against Endeavour's upper midbody, the orbiter and enclosure doors were opened and SHOOT was moved into Endeavour. The PGHM was used to slide SHOOT into its planned spot between the Spacehab and GAS Bridge.

The Mysterious 'Bang'

On the morning of the installation I was at a yearly Space Congress meeting in nearby Cocoa Beach when Endeavour's Flow Director, also attending the yearly event, pulled me aside. He told me that workers in the aft engine compartment of Endeavour had heard a very loud and unexplained noise - a "bang" - and felt the orbiter shudder on the prior evening. No indication of the cause had been found. No damage was seen and nothing was out of place. But it had to be dealt with. For the next few weeks the launch crews examined all possible causes. Even earthquakes and possible sonic booms were investigated. All of the Shuttle systems, as well as the launch pad and service structure were examined and "fault trees" that might have caused the incident were examined. This included payloads and each of the payloads were analysed to see if any possible cause might be found.

Eventually, the cause was traced to a support structure inside a 17 inch propellant line in the orbiter's aft propulsion compartment. Borescope pictures and video confirmed, by the markings on the parts, that two segments of a ball socket assembly had been slightly out of position when the Shuttle arrived at the pad and had shifted into position as engine launch

pad checkout preparations began; thereby causing the noise. This analysis and study took quite a few weeks of effort.

The analysis, photos, and videotape of the borescope views were features of each succeeding mission readiness review as the attendance at each review is a bit different. By launch time, those of us at KSC had seen the "bang" analysis enough times to almost repeat it by rote.

Launch Pad Tests and Final Activities

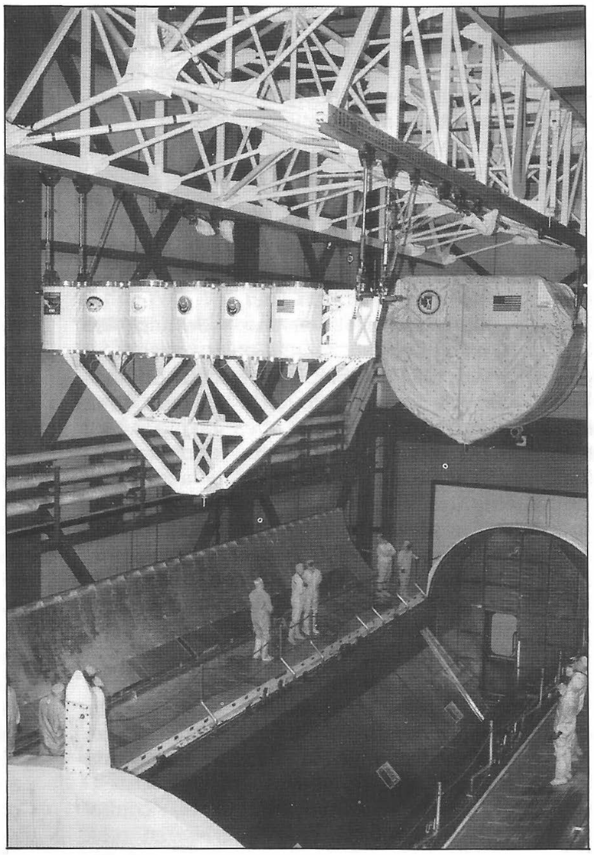
Preparations for the launch were continuing and during the second week in May the combined team performed a simulated launch countdown that lasted several days. During the time that the orbiter was simulating its final countdown hours and working through simulated problems, we in the payload world were doing likewise with a communications links with Johnson Space Center at Houston. These simulated problems were not known before the exercise and they were given to the team by the simulation organisers who hoped to make the exercise as "interesting" as possible. Exercising the management and engineering network in order to practice solving possible launch day problems was our primary aim and the exercise was extremely useful.

The following week, after we had been cleared off the pad for several days as the orbiter loaded its toxic hypergolic propellants, we did the Spacehab module stowage of non-time critical experiments and replaced an accelerometer package that had been removed for modification. This had been planned originally as a practice session and provided us with experience in hoisting technicians and equipment down into the Spacehab module via the crew cabin.

The Shuttle programme had two major STS-57 management reviews in late May. The Launch Readiness Review which defined our readiness to launch and Flight Readiness Review which defined the programme's readiness to conduct the mission and confirmed the proposed launch date.

At this point things were looking good for an early June launch. However, we learned that preload springs in the engine's oxidiser pumps might have the inspection stamp placed in a stress-critical area. After extensive search of records and analysis, Shuttle programme managers decided that replacing the Shuttle engines' pumps would be the most prudent course. This was done during late May and early June. We took advantage of this extra time at the launch pad to practice powering up the Spacehab module in the same manner as we would for launch in order to assure ourselves that we could meet the countdown timeline. Prelaunch activation of the Spacehab module was set for launch minus 38 hours with the late access stowage operation to last from minus 35 hours to minus 28.5 hours. Spacehab would remain powered up through launch and ascent, but SHOOT would not be powered up at launch and the flight crew would activate that payload on-orbit.

The final cryogenic helium service for SHOOT began on June 16 and lasted for over 24 hours as planned. Shortly after the SHOOT operations were complete at launch minus 64 hours the orbiter began operations to close the payload bay doors. This was followed by fuel cell reactant operations to load cryogenic hydrogen and oxygen into the Endeavour to provide electric power during the flight. This was a hazardous activity and after its completion we began the Spacehab final power-up for launch and final stowage of Spacehab module experiments and the closing of Spacehab's hatch for launch.



Two of the payloads for mission STS-57 are being transferred from the canister transporter into the payload bay of the orbiter Endeavour, undergoing preflight processing in the OPF. On the left are the Get Away Special canisters attached to a GAS Bridge Assembly, and on the right is the Spacehab module. *NASA*

Weather Delays Launch

On Sunday June 20 we had planned to launch STS-57 at 9:37 am. The countdown itself had gone smoothly but the weather was not cooperating. In the firing rooms at KSC the weather channel was one of the most popular views on our console television screens. We were having no problems with the hardware so the morning was spent at our consoles looking alternately at the Firing Room windows to check the weather that we had outside and the television screen with its radar monitor view to check the weather that we were going to have.

Both at KSC and at the transatlantic abort sites the weather was in and out of specifications. When we reached the Launch minus 9 minute built-in-hold the Launch Director elected to stay in the hold and hope for the weather to improve. The possible launch window was an hour and eleven minutes long and as we approached the end of that time we picked up the countdown and went down to launch minus five minutes and held in case there was a last minute weather reprieve. There is no built-in-hold at minus five minutes, but it is the last time we can hold without starting up the orbiter's auxiliary power units. These units burn hydrazine to provide hydraulic power to the control surfaces and have only limited operating times on the ground.

June 20 was not to be. The launch was scrubbed for the day and rescheduled for the next day. A 24-hour recycle was possible as no mechanical or electrical problems were involved. The only payload activity required was to remove and replace one of our experiments in the crew cabin area, and that went well.

Of course it was a disappointment. Particularly so in that no Shuttle problems were at fault. The scrub happened on a Sunday and between the mass of launch sightseers who were trying to get home, the mass of KSC workers trying to get home and the mass of Sunday afternoon beach goers trying to get onto Cocoa Beach, the traffic in the area was at a very slow crawl. Shortly after getting home it was time to get to bed for the next launch attempt.

Next Day Launch

I arrived at the Launch Control Center at 3:00 am for the next try at launching STS-57. The ground floor of the Launch Control Center has a lobby almost two stories high and the flags of the Shuttle fleet hand down from the ceiling like the banners in a medieval baronial hall. Each flag is a large white diagonal, framed above and below by red and blue, with the name of one of the orbiters on the white diagonal. On the North wall are the mission emblems of all of the manned space flight missions launched from this control center dating from the Apollo missions to the last Shuttle mission. Each time that I passed through I always felt a strong sense of tradition and history there.

When I reached the Firing Rooms and checked the countdown status I found that the Shuttle was in good shape and the delay had caused no ill effects. The weather also cooperated and the countdown was going exceptionally well. We were hoping for a liftoff exactly on time. The liftoff time today was 30 minutes earlier than the previous day due to the orbital parameters involved in the planned rendezvous with the Eureca satellite.

Such was not to be. After coming out of the T-9 minute built-in-hold Range Safety reported an unauthorised aircraft was in the danger area. They were trying to warn the aircraft off as we approached the T-5 minute point. When the count reached T-5 minutes we had to hold to avoid starting

the auxiliary power units prematurely. No sooner had the Launch Director held the count then Range Safety reported the aircraft clear! The Director immediately called for the count to resume. But, we had lost 22 seconds in holding and re-starting the count. Launch was 22 seconds late. Not bad - but not perfect.

In the Firing Rooms we had to wait a bit to see the actual launch without using the TV as it took a moment for the Shuttle to rise past the bottom of the huge sloped windows at the front of the room. As it had launched from Pad 39B - slightly North of 39A - the Shuttle climbed at what looked, to us, like a slight North to South angle as it headed out on its inclination of 28.45 degrees. The brilliance of the engine's exhaust from three and a half miles away was hard to watch - but we watched. And we stayed at our consoles and watched the tracking figures until MECO: Main Engine Cut Off.

After Endeavour's main engines shut down everyone repaired up to a small crowded hall on the fourth floor of the Launch Control Center for the traditional "Eating of the beans". It has become a tradition that the launch crews share a serving of beans and cornbread after the Shuttle launches - whatever time of day it launches. These are cooked in electric pots during the final countdown hours and occasionally the pungent smell of beans drifts into the Firing Rooms - making the long hours to launch even longer. The beans and cornbread always taste wonderful regardless of whether we have them at dusk, dawn, midnight or noon. They are always excellent - and the STS-57 beans were no exception!

Flight Day One

Endeavour's launch at 9:07:22 am on June 21 was followed by a successful ascent and, after arriving on orbit, its payload bay doors were opened exposing the orbiter's radiators as well as the payload complement for the mission.

In the forward end of the payload bay was the 9,628 pound Spacehab pressurised module connected to the middeck area by a short passageway that allowed the crew access during the mission. Just behind Spacehab was the 3,570 pound Superfluid Helium On-Orbit Transfer experiment (SHOOT) to study the behaviour of superfluid helium in space during the first days of the mission. Just behind SHOOT was a space where the 9,800 pound satellite Eureca would be berthed following its retrieval during the mission. At the aft end of the payload bay was the 5,652 pound GAS Bridge Assembly.

Mission specialists Janice Voss and David Low began activation of the Spacehab module at 11:05 am (all times are KSC times) and at 12:41 mission specialists Janice Voss and Jeff Wisoff, together with mission commander Ron Grabe and pilot Brian Duffy, entered the Spacehab module for the first time in space.

At four hours into the mission the crewmembers began activation of Spacehab experiments on crystal growth, plant growth and biomaterials.

During the afternoon Ron Grabe fired Endeavour's small reaction control system jets in the first of a series of manoeuvres to raise Endeavour's orbit as it flew towards its rendezvous with the Eureca satellite.

Endeavour was circling the Earth every 93 minutes in an orbit of 252 by 212 nautical miles and was closing with the Eureca satellite at a rate of 171 nautical miles per orbit with a scheduled retrieval of Eureca on the fourth day of the mission.

Flight Day Two

Early on this second day the Spacehab module's Bioserve Pilot Laboratory, which is designed for use in growing bacteria specimens in space, was turned on. The bacteria studied on STS-57 included a plant root bacteria useful to agriculture and bacteria useful in pharmaceutical manufacturing. Also in operation on the second day was Spacehab's Liquid Encapsulated Melt Zone (LEMZ) experiment, a study of growing highly pure crystals via a "floating zone" method that takes advantage of weightlessness to allow the crystals to be grown without being held by a container.

Other activities for the crew included turning their spacecraft end-over-end for a test with the SHOOT payload. Endeavour was steered through a series of somersaults, the fastest ones taking about two minutes to complete, and then its steering jets were fired to accelerate slightly. The engine firings and manoeuvres were designed to slosh the helium in the SHOOT dewar tanks so that engineers on the ground could study the effects. The SHOOT experiment conducted two helium transfer operations during the day.

David Low and Nancy Sherlock checked out Endeavour's Remote Manipulator System (RMS) robot arm for use later in retrieving the Eureca satellite and supporting EVA operations.

At 1:49 pm Grabe fired reaction control thrusters to align Endeavour in an orbit exactly below Eureca and to adjust the closing rate. Endeavour was then in an orbit with an apogee of 253 nautical miles and a perigee of 217 nautical miles and was catching up Eureca at a rate of 185 nautical miles per orbit from a distance of 2,964 nautical miles behind.

Flight Day Three

Ron Grabe fired Endeavour's manoeuvre engines at 1:08 pm and 1:55 pm to close in on Eureca and to place Endeavour in a co-elliptic orbit with the satellite. Endeavour was then 291 nautical miles behind Eureca and closing at 32 nautical miles per orbit.

The STS-57 flight crew continued to support SHOOT helium transfer operations with firings of the orbiter's thrusters. Brian Duffy performed experiments in microgravity soldering at a special workbench in the Spacehab module. This included both soldering connections and removing solder from connections.

David Low and Jeff Wisoff with the assistance from Brian Duffy checked out the space suits that Low and Wisoff would wear later on the mission during their EVA.

Flight Day Four

The crew of Endeavour was awakened on the day of their Eureca rendezvous at about 1:00 am by Mission Control playing a 1974 tune titled "Rendezvous".

The Eureca retrieval was the major item on Endeavour's agenda for that day. At 6:00 am Endeavour was only about 25 nautical miles behind the Eureca and closing slowly. At about 7:30 am the Terminal Interception engine burn was performed when the orbiter was about 8 nautical miles distant and behind Eureca. Approximately an hour later mission commander Ron Grabe took manual control of Endeavour's flight controls for the final approach to Eureca.

Eureca's controllers at Darmstadt, Germany commanded the satellite's solar panels to fold up and then commanded the two radio antennae to retract as well. Eureca's two solar panels retracted and latched into place as planned. However, Eureca controllers could not get the two radio antennae completely into position for a positive latch indication. The number one antenna was about four degrees from complete retraction and the number two antenna was two degrees out of position. After an additional attempt to drive both latch motors in the primary and redundant modes, payload controllers and the Houston Mission Control team decided to berth the satellite with the antennae unlatched.

Mission specialist, and payload commander, David Low used the RMS arm to grab the satellite by the grapple fixture which had been attached to Eureca before its launch in 1992. Eureca was placed in Endeavour's payload bay, latched in place and at 12:42 pm the umbilical arm which carried power from Endeavour to Eureca's thermal control units was locked into place on the satellite.

During the crew's sleep period the Eureca payload controllers and Mission Control teams were active in analysis of three possible options for dealing with the antennae. The first option called for spacewalking astronauts to manually hold down the antennae booms while Eureca controllers sent computer commands to drive the latches closed. The second option had the astronauts tie down the two antennae to the satellite structure. The third option had the two spacewalkers removing the antennae from the Eureca and stowing them in Endeavour's cabin.

Flight Day Five

Early this morning, mission commander Ron Grabe fired Endeavour's orbital manoeuvring engines to drop the low point of the Shuttle's orbit by about 45 nautical miles in order to enhance the landing opportunities available at the end of the mission. Endeavour was then in an orbit with an apogee of 256 and perigee of 210 nautical miles.

The crew was successful in securing the Eureca radio antennae during their scheduled EVA spacewalk operations. The planned four hour and twenty minute EVA was extended to five hours and fifty minutes to accommodate the antennae operations. At the beginning of the EVA

activity David Low mounted a small foot restraint platform at the end of the RMS robot arm and Nancy Sherlock positioned the arm so that Low could gently push against the Eureca latch mechanisms. Payload controllers then drove the latches to secure the antennae.

Flight Day Six

The day's work focused on experiments in Spacehab and an experiment in the orbiter middeck.

Brian Duffy and Jeff Wisoff worked on several test setups of the middeck Fluid Acquisition and Resupply Experiment (FARE) which evaluates techniques that can be used to develop methods of refuelling spacecraft and transferring fluids in orbit. Fluid was transferred between two transparent tanks while Endeavour's steering jets were fired for small accelerations.

Janice Voss worked on the Spacehab LEMZ experiment which uses a process called floating zone crystal growth. If processes can be refined to commercially produce large pure crystals such as gallium arsenide, they could contribute to the next generation of high-speed computer, optics, and sensor systems.

A planned test calling for the shut down of one of Endeavour's fuel cells was terminated when the hydrogen reactant valve would not close. The test related to studies of having the Shuttle stay for long periods at the Space Station. Fuel cell number three, which had been the subject of the test, was restarted without incident. The test was designed to study the fuel cells' performance when turned off and then back on in space. Further tests are planned on future missions.

Flight Day Seven

Ron Grabe, Brian Duffy and Janice Voss participated in the Neutral Body Position study. Flight surgeons have noted on previous flights that the body's basic posture changes in microgravity. This postural change, sometimes referred to as the "zero-G crouch", is in addition to the lengthening of the human spine during space missions. In order to document this condition throughout the duration of a space mission, still and video photography of crewmembers in a relaxed position are taken early and late in the mission. These findings will be included in the design of future spacecraft and orbital work stations.

Nancy Sherlock stepped through the electronics procedures portion of the Human Factors Assessment. She set up a work platform then hooked up a notebook computer and went through a simulated computer procedure for a space station propulsion system. These studies rely on the astronaut's feedback for planning future longer-duration missions. Crew members will increasingly rely on computer procedures instead of paper documents for maintenance and operations of spacecraft and experimental equipment.

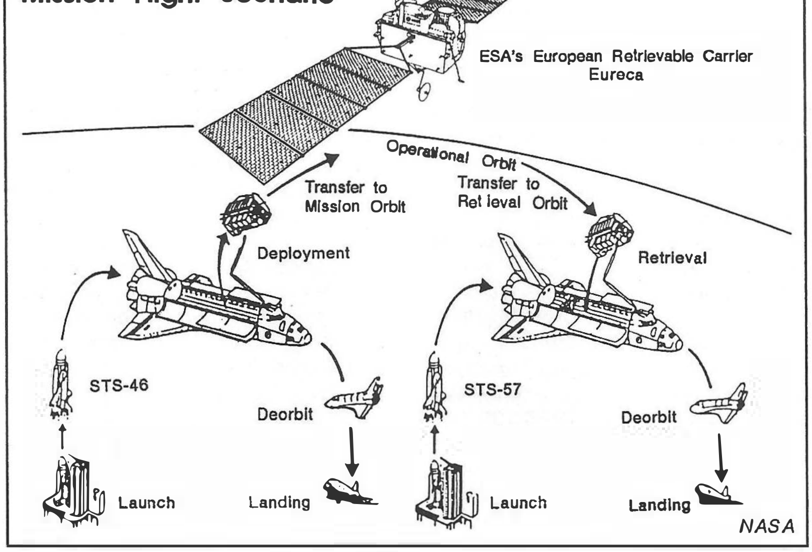
Flight Day Eight

The crew checked out the orbiter's flight controls for the landing of STS-57, then set for the following day, June 29.

Mission specialists Nancy Sherlock and Janice Voss performed a plumbing repair job on the EFE experiment in the Spacehab module. EFE uses a mixture of water and potassium iodide to simulate wastewater in a study of wastewater purification in microgravity.

The crew began what was then thought to be their last sleep period at about 3:00 pm on the 28th. The orbiter was scheduled to land the following day at 8:44 am on June 29. Weather predictions were for marginal but potentially favourable weather at the Florida landing site at that time.

Mission Flight Scenario



Flight Day Nine

Routine prelanding operations were carried out and by 6:00 am Endeavour had closed its payload bay doors in preparation for the landing. Two landing opportunities existed at KSC on the 29th - one at 8:44 am and a second at 10:23 am. Edwards Air Force Base was not considered as a backup for this day.

Low clouds at KSC's Shuttle Landing Facility and possible rain showers caused missions controllers to hold off on the deorbit burn of the orbiter's engines. The weather continued to be unsuitable for landing and the return to Earth was delayed for a planned 24 hours. The crew reopened the payload bay doors to expose the orbiter's radiators and provided status reports on middeck experiments. They then prepared their vehicle for an additional overnight stay in space. Endeavour was then in a 257 by 208 nautical mile orbit.

Flight Day Ten

The crew were awakened for the next landing attempt at 7:59 am on June 30 at KSC with a backup opportunity at Edwards Air Force Base, California at 9:28 am.

June 30, however, was also not to be. Once again unsuitable weather prevented the landing at the Florida launch site. However, the weather patterns appeared favourable for a landing the following day, July 1. Mission controllers chose to attempt the landing on the next day rather than land in California.

During their shortened work day the crew set up the bicycle ergometer and monitoring equipment for an experiment investigating aerobic exercise as a counter to the dizziness that astronauts sometimes experience upon return to Earth's gravity. The study compared readings from various body systems as the astronaut exercised vigorously on the stationary bicycle. Measurements from pre-flight exercise, mission-day three, pre-landing day and post flight are compared to evaluate aerobic exercise as a countermeasure against the physiological effects of microgravity during longer space missions.

Late on the evening of the 30th the crew went to sleep for what proved to be their last night in space.

Flight Day Eleven

The flight controllers at Mission Control awakened the astronauts for their last day with the music "I'll be home for Christmas" in view of the delayed landing. The last Shuttle mission whose landing had to be delayed due to weather for as long was STS-32. Coincidentally mission specialist David Low was a crewman on that flight also. In STS-32's case however the landing was switched to Edwards Air Force Base.

The day dawned bright and clear at KSC with no sign of the previous two days' clouds. The crew performed their prelanding checks and at approximately 7:41 am the deorbit burn was performed. The orbiter reentered the effective atmosphere over the Pacific Ocean and passed over Texas and the Gulf of Mexico as it approached central Florida. Twin sonic booms announced Endeavour's return as it passed over KSC and turned into its approach to runway 33.

The orbiter touched down at 8:52 am on July 1, 1993 and rolled 9,870 feet to wheelstop after a flight of 9 days, 23 hours, and 46 minutes.

On the same launch pad from which Endeavour had launched - pad 39B - Discovery was undergoing a practice launch countdown as Endeavour landed. After the landing the Discovery crew radioed Endeavour to say they were "right behind you".

After the crew had left Endeavour, ground crews removed time-critical experimental samples and results from the orbiter cabin and Endeavour was towed to the OPF. The STS-57 astronauts returned to Houston later on the same day.

SATELLITE DIGEST-256

Satellite Digest is our regular listing of world space launches. It is abridged from a more detailed monthly listing, Worldwide Satellite Launches prepared by Phillip S. Clark and published by the Molniya Space Consultancy.

Spacecraft	Int'l Desig.	Launch	Launch Site	Launch Vehicle	Mass kg	Orbital Epoch	Inclin. deg	Period min	Perigee km	Apogee km	Notes
Cosmos 2251	1993-036A	Jun 16.18	Plesetsk	Cosmos-B	900 ?	Jun 17.43	74.04	100.74	781	806	[1]
Endeavour	1993-037A	Jun 21.55	KSC	Shuttle	101,656	Jun 24.58	28.46	94.17	475	482	[2]
Cosmos 2252	1993-038A	Jun 24.18	Plesetsk	Tsyklon	225 ?	Jun 25.04	82.59	114.77	1,409	1,481	[3]
Cosmos 2253	1993-038B				225 ?	Jun 25.03	82.59	114.17	1,410	1,425	
Cosmos 2254	1993-038C				225 ?	Jun 25.11	82.58	113.87	1,393	1,415	
Cosmos 2255	1993-038D				225 ?	Jun 25.03	82.62	114.01	1,404	1,417	
Cosmos 2256	1993-038E				225 ?	Jun 25.11	82.58	113.96	1,401	1,415	
Cosmos 2257	1993-038F				225 ?	Jun 25.11	82.58	114.10	1,410	1,420	
Galaxy 4	1993-039A	Jun 25.01	Kourou	Ariane 42P	2,988	Jun 30.02	1.07	1,073.95	20,860	35,862	[4]
Resurs-F 18	1993-040A	Jun 25.35	Plesetsk	Soyuz	6,300 ?	Jun 26.06	82.58	89.14	223	241	[5]
RADCAL	1993-041A	Jun 25.98	WR	Scout G-1	87	Jun 26.10	89.56	101.37	759	888	[6]
Navstar 21	1993-042A	Jun 26.56	ER	Delta-2	1,881	Jun 26.43	34.72	356.77	187	20,383	[7]

NOTES

1. Cosmos 2251 is believed to be a military store-dump communications satellite: its orbit is co-planar with that of Cosmos 2112.

2. Carried six astronauts: R J Grabe (commander), B Duffy (pilot), G D Low (payload commander and mission specialist 1, MS-1, EVA astronaut), N J Sherlock (MS-2), P J K Wisoff (MS-3, EVA astronaut) and J Voss (MS-4). Orbiter payload bay carried SPACEHAB-1 (mass 4,367 kg) non-separating payload into orbit. Performed rendezvous with European Eureca satellite which had been launched aboard Atlantis/STS-46 in July 1992. Eureca (projected mass when berthed in payload bay 4,445 kg - 9,800 lb) was captured by Endeavour 1993 Jun 24.58 (13.53 GMT) and returned to Earth aboard the orbiter. Mass quoted above is that projected for landing. Launch time was 13.07 GMT and landing at Kennedy Space Center was 12.52 GMT.

3. Six second generation military field communications satellites, launched by a single booster. Satellite orbits are almost co-planar with those of Cosmos 2197-2202.

4. Galaxy 4 is a telecommunications, television and data transmission satellite, launched for Hughes Communications Inc in U.S.A. Satellite mass at launch is given above: at the beginning of operations the mass is 1,692 kg and the mass projected for the end of operations is 1,323 kg. Satellite to be located over 261 °E.

5. Twelfth flight of the Resurs-F1 class satellite since payloads started to be launched under the Resurs-F name: satellite undertaking remote sensing mission.

6. RADCAL is a radar calibration satellite, launched for the USAF. It is to broadcast for a year, permitting its position to be tracked using Navstar/GPS satellites and ground-based radars around the World. The satellite also carries an experimental device to test a more efficient way of charging batteries on military and civilian spacecraft that use solar batteries.

7. Twelfth flight of a Block 2A Navstar satellite (USA 92). Mass quoted above includes propellant: dry mass is 930 kg. Delta second stage carried supplementary Plasma Motor Generator (PMG) experiment, a follow-on to SEDS carried aboard the Navstar 19 second stage (1993- 017B-C).

ADDITIONS AND UPDATES

1993-021A Cosmos 2240 was recovered approximately Jun 7.5, approximately matching the longer-than-normal lifetime of Cosmos 2231.

1993-031B Add a further orbit for Arsene: Jun 8.17, 1.10°, 1,029.52 minutes, 17,699 km, 37,094 km.

1993-032A Add a further orbit for Navstar 20 (USA 91): Jun 14.71, 54.95°, 717.92 minutes, 20,034 km, 20,328 km.

1993-033A The launch time for this mission was May 31.39. Resurs-F 17 was recovered approximately Jun 20.2.

1993-035A The correct launch time for the Molniya-1 86 mission is May 26.14. Add a second orbit for the satellite: Jun 2.87, 62.82°, 716.69 minutes, 426 km, 39,876 km.

Mir Mission Report

Mir Enters Eighth Year in Orbit

Manakov and Poleshchuk's Mission to Mir: January to July 1993

On January 24, Soyuz TM-16 was launched with Manakov and Poleshchuk on board and two days later they transferred to the Mir space station (*Spaceflight*, May 1993, p.173). Before their return to Earth on July 22, Manakov and Poleshchuk had carried out a busy work schedule of medical and scientific experiments and space station maintenance. Three Progress supply spacecraft docked with the Mir during this time and two EVAs were carried out. *Neville Kidger* reports the details.

BY NEVILLE KIDGER
Leeds, UK

Marking the Anniversary

February 20 was the seventh anniversary of the launch of the Mir base block and the Russian media took time out to assess its current status, reporting that it was hoped that the station would operate until 1996.

The initial life of the station was planned to be three years, but with a great amount of careful maintenance, the station has lasted for seven years so far. The automatic life-support system has been changed five times to date and a flag has been erected and taken down on the large Sofora mast once. The station has also been repaired after cosmonauts broke a docking antenna and the Kvant-2 EVA hatch.

The station has suffered from flaking paintwork, condensation, a reported foul odour and corroding pipes. Cosmonauts have spent long periods of time on repair and maintenance. However, the TV noted that neither the Americans nor the Europeans had a facility in space like the Mir station.

Although three separate modules had already been launched to the complex since 1987, two more remained to be launched and were scheduled although the scientific equipment for the first of the modules, Spektr, had still to be installed. The final module, Priroda, would be launched later.

The Russian news agency noted that the Buran shuttle orbiter was still scheduled to fly to the complex and dock with it in 1994. A docking with the American shuttle orbiter was to take place some time after that.

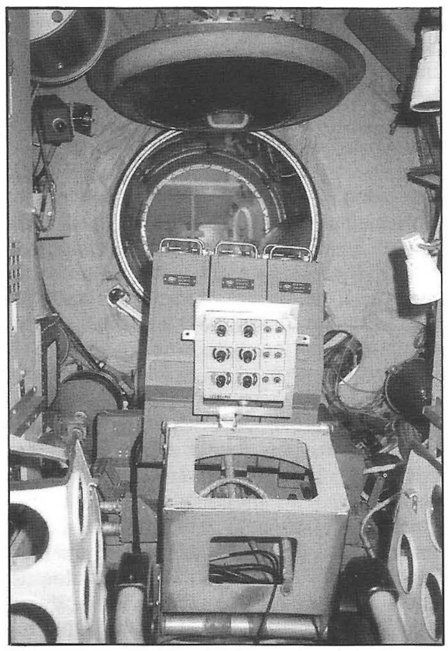
Progress M-16 Resupplies Mir

The launch of Progress M-16 took place at 1832 GMT on February 21 from the Baikonur Cosmodrome. The initial orbit of the craft was given as 254 x 191 km with a period of 88.7 minutes.

The unmanned craft docked with the Mir station at 2017:57 GMT on February 23. It delivered 2,598 kg of equipment and consumables to the complex.

On March 2 Manakov and Poleshchuk were scheduled to replace the old air-conditioning unit with a new one delivered by the M-16 cargo ship. Three days later they conducted an experiment with the air-conditioning unit of the life-support system and checked out its safety. They also replaced one of the units of the communication system which provided communications to Earth via the Altair relay satellite (Kosmos 2059). Also on that day they conducted the first in a long series of operations to provide the Kvant-2 resupply module with additional gyroscopic stabilisers delivered by the M-16 craft.

Over the next two days the men installed new equipment delivered by the cargo ship. They assembled frames for additional gyros in Kvant-2 and checked the pressurisation of the system for vacuuming them, checking out the operation of the on-board computing system after replacing worn-out electronic units.



Inside the Kvant 2 module looking towards the EVA hatch and airlock . The MKF-6MA camera is in the foreground. (This photograph was taken in the Cosmonaut Training Centre (TsPK) at Star City.) *Karl Heinz Rohrwild*

The work to replace the gyros continued on 9 March and the complex was then scheduled to be replenished with oxidiser from the tanks of the cargo ship.

On March 19 the men carried out work to connect the electricity supply of the Kristall and Kvant-2 modules in order to increase the effectiveness of their solar arrays. Control tests of the functioning of the new gyroscopes in the Kvant-2 module were conducted during dynamic operations in controlling the movement of the complex. Two corrections of the complex's trajectory were accomplished using the cargo craft's engine.

The ITAR-TASS agency reported on March 26 that the Progress M-16 mission was coming to an end. But first the craft was used in a test of remote control of an orbital cargo ship. At 0650 GMT on March 26 it was undocked from the Mir complex and was commanded by the two cosmonauts to retreat to a distance of 70 m from the complex. From this distance the cosmonauts commanded the unmanned cargo ship to approach the complex and to successfully dock, reportedly at 0707 GMT.

The final undocking of the cargo ship was commanded at 0421 GMT on March 27, the initial stage of the separation being commanded by remote control by the cosmonauts. The end of the flight was controlled by the staff at the Kaliningrad Flight Control Centre (TsUP) near Moscow, the craft being commanded to fire its engine and descend into the Earth's atmosphere where it was destroyed, as planned.

Progress M-17 In Flight

The launch of the next cargo ship, Progress M-17, was at 0334 GMT on March 31. The craft entered into an initial orbit of 238 x 178 km with a period of 88.5 minutes. After two days of approach manoeuvres it docked with the Mir complex at 0516:18 GMT on April 2 at the rear docking unit of the Kvant astrophysics module. The complex was then in an orbit of 393 x 395 km.

After docking the cosmonauts began unloading the 2.5 tonnes of supplies and prepared test equipment for upcoming experiments.

During April 9 the cosmonauts were scheduled to use French dosimeters to study the radiation levels in the complex and measure the ionising radiation along the flight path of the complex. This was to be recorded and returned by telemetry to the TsUP.

First EVA

Exit from the complex was planned for 2125 MT on April 19. The EVA was intended to install an electric drive for the Kristall solar batteries which were to be mounted on the Kvant astrophysics module. The hatch was actually opened at 2115 MT as the complex passed some 400 km over China.

Upon leaving the EVA hatch, Poleshchuk made his way down the Kvant-2 module to the base of the large telescopic boom which had been erected years before to aid movement around the exterior of the station. Manakov then moved over to the end of the telescopic boom and was swung over to the work site on the astrophysics module. Containers with the electric drives were located on the exterior of the complex and the cosmonauts moved them to the work site

using the boom.

By the beginning of the third hour of the EVA the cosmonauts had transported one container and had slipped on their time table by about 10 minutes. There was also a problem with the ventilation of Poleshchuk's EVA suit. Telemetry showed that there was a reduction in the supply.

They then attached the drive with "great difficulty" onto the specially-constructed truss framework built earlier on the Kvant astrophysics module and connected plugs into the mains electrical supply.

As Poleshchuk returned to the station he noticed that one of the two control handles of the telescopic boom had been detached and had floated away. It was immediately obvious that a replacement was needed for the continuation of the planned EVAs. According to Aleksandr Aleksandrov, an ex-cosmonaut and an engineer at the Energiya NPO, the cosmonauts could either try to make a handle themselves or one could be sent up from Earth.

The two men's first EVA lasted for 5 hours and 25 minutes. Russian TV revealed that, for the first time ever, cosmonauts were working on a contract basis outside the complex. The men were expected to be paid about one million Roubles for their three EVAs, presenter Sergei Slipchenko noted. However, later reports declined to reveal an actual figure. This was said to be due to the unpredictability of the spiralling of prices.

Work Inside the Complex

Following their work in open space, the men spent the next few days conducting regular maintenance work on the water regeneration system, the electricity supply system and the on-board computer complex. April 23, the planned date of the second EVA of the series, had been cancelled.

Between 7 and 10 May the two cosmonauts conducted astrophysical and technical experiments, setting up and checking equipment delivered by Progress M-17. Several series of experiments using the French-made Nausicaa experiment to detect ionised radiation were conducted. They also conducted another Resonance experiment series to test the dynamic characteristics of the orbital complex.

During a radio link-up on May 10 the men called for the payment of additional allowances for cosmonauts undertaking space missions in the same manner as those people going on business trips. They said that cosmonauts had children and families too. They called for a review of the Welfare provisions given to cosmonauts.

ITAR-TASS revealed on the same day the next Progress M cargo ship was to be launched on May 19. It was to carry a replacement handle for the telescopic arm and also equipment for the upcoming Russian-French mission scheduled for launch on July 1.

Progress M-18 Into Space

The expected launch of the Progress M-18 cargo ship on 19 May was postponed for three days following the failure of the Kosmos 2243 satellite during a Soyuz launch on April 27 from Baikonur. This latter spacecraft disintegrated at the moment of separation from the Soyuz's third stage, possibly due to either residual propellants in the Soyuz or the accidental activation of the Cosmos' self-destruction system. (See "Satellite Digest - 255" in ***Spaceflight***, August 1993, p. 280).

The launch of Progress M-18 occurred at 0642 GMT on May 22 and the craft was placed into an initial orbit of 258 x 194 km with a period of 88.7 minutes. It docked with the forward axial docking unit of the base block of the Mir complex at 0825 GMT on May 24. It was another first in the annals of the Salyut and Mir programmes - for the first time two unmanned cargo ships were servicing a manned complex. (Soyuz TM-16 was docked with the front port of the Kristall module using the APAS-89 docking unit.)

As well as carrying various replenishment materials, the cargo ship also featured a ballistic return capsule for the return of the results of the experiments. By May 28 the refuelling of the complex using the supplies delivered by M-18 had begun.

On June 4 ITAR-TASS reported that the cosmonauts had been spending the past week unloading the cargo craft and fitting the delivered equipment into place. This included the installation of new electronics units in the complex's computers and the replacement of water pumps in the circuit of the temperature control system. On the same day the orbit of the complex was corrected using the M-18 engines.

EVA on June 18

By the evening of June 18 the men were completing preparations for an EVA to be conducted that evening. The walk was planned to last for 5 hours and would involve the repair of the telescopic arm and the installation of the second electric drive to the truss mounted on the Kvant astrophysics module. The plan was for the cosmonauts to open the Kvant-2 hatch at 1732 GMT and return at 2240 GMT.

The next day the Russian ITAR-TASS agency reported that the men began their EVA at 1725 GMT and had succeeded in their tasks. The replacement handle on the telescopic arm was installed and the cosmonauts had used the arm to move around the station installing the second electric drive.

The electrical connections with the Kvant module were made and the men spent some of their time taking TV pictures of the exterior of the station, which Moscow TV described as "pretty threatening".

The cosmonauts returned into the craft after an EVA lasting 4 hours and 33 minutes. Manakov and Poleshchuk were reported to be in good health and spirits.

"Altair" Mission Preparations

On Earth the focus had begun to shift to the next crew rotation, which would also be the fourth flight to a Soviet/Russian space complex of a French cosmonaut.

The new flight - codenamed "Altair" (after the star in the constellation of Aquila) - came about as the result of an agreement signed between the Russian Space Agency and the French Space Agency, CNES, on 28 July 1992 after the launch of the joint "Antares" mission during which Frenchman Michel Tognini conducted experiments on the Mir complex in July and August 1992.

The agreement guarantees the implementation of conventions entered into by the former Soviet Union. The agreement covered two missions, the first is "Altair" and the second is "Cassiopea" which is planned for launch in 1996.

On June 24 a state commission approved the choice of crew for the "Altair" mission. The prime crew was confirmed as: Vasili Tsibilyev and Aleksandr Serebrov with Frenchman Jean-Pierre Haignere, their back-ups being Russians Viktor Afanasyev and Yuri Usachev with French woman Claudie Andre-Deshays.

The joint crew was to conduct over a dozen experiments during a three week mission commencing on July 1. There would be six medical and two technical experiments using equipment delivered for the 1992 Russian-French joint flights. Two of the "Antares" experiments had been operated continuously on the Mir complex since August 1992 and would end with the completion of the "Altair" mission. In addition the crew would activate six life sciences experiments including a new one called "Synergies", one fluid physics experiment and two technology experiments during the planned 19-day joint mission on Mir.

Manakov and Poleshchuk Return Tsibilyev and Serebrov Take Over

On July 22 1993 the Soyuz TM-16 spacecraft descent cabin landed back on Earth delivering three cosmonauts - the two-man Russian crew of the Mir orbital station who, as the 13th main expedition to the complex, had been resident since late January, and the French cosmonaut, Jean-Pierre Haignere, who was completing his country's fifth manned space mission in conjunction with either the Soviet, Russian or American space agencies.

During their mission, Gennadi Manakov and Aleksandr Poleshchuk, had conducted many experiments including a spectacular test of a prototype solar sail and they undertook two separate EVAs.

During the 21-day joint Russian-French mission, the two resident cosmonauts were replaced by a new pairing, Vasili Tsibilyev and Aleksandr Serebrov, who are due to stay until November 1993 when they will be relieved by a three-man crew. One of the three, a medical doctor will stay on the complex for about 16 months accompanied by succeeding pairs of cosmonauts.

During their planned 4-month mission, Tsibilyev and Serebrov are scheduled to undertake three separate EVAs and to erect a new girder structure.

BOOK NOTICES

These notices, compiled by L.J. Carter, are not intended to be reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

Full publication details are given for each book to enable copies to be ordered from a local bookseller, if desired. The address of each publisher also appears, for many items can now be ordered direct from them. If not, they will supply the address of a local agent who can handle matters.

Alexander A. Friedmann: The Man Who Made the Universe Expand

E.S. Tropp *et al.*, Cambridge University Press, The Edinburgh Building, Cambridge CB2 2RU, 267pp, 1993, £30.

Our Universe can be described, mathematically, by a simple model developed in 1922 by Alexander Friedmann (1888-1925) who predicted - long before there was any observational evidence - that the whole Universe would expand and evolve with time.

This is probably the first detailed biography of an outstanding Soviet physicist, set against a wide historical background and providing data on his school and university years, military service and teaching and research, and bearing in mind that his work in theoretical cosmology (1922-24) was developed within the organisation of Soviet science at that time. Extensive use has been made of contemporary material and the reminiscences of colleagues.

UV and X-Ray Spectroscopy and Astrophysical Plasmas

Eds. E.H. Silver and S.M. Kahn, Cambridge University Press, The Edinburgh Building, Cambridge CB2 2RU, 610pp, 1993, £50.

Ultraviolet and X-ray spectroscopy of both astrophysical and laboratory plasmas is of interest to many scientific disciplines. In astrophysics, the Hubble Space Telescope, Astro I and ROSAT observatories are providing UV and X-ray spectra and images of cosmic sources in unprecedented detail, while the Yohkoh mission recently collected superb data on the solar corona.

The development of ion-trap facilities and novel laser experiments in the laboratory are providing vital new data on high temperature plasmas. Recent innovations in the technology of spectroscopic instrumentation are also important.

For these reasons, the papers that comprise this volume, from a team of international specialists, constitute a timely up-to-date review of developments in short-wavelength spectroscopy and provide a solid introduction to its theoretical and experimental foundations.

The Cambridge Guide to Astronomical Discovery

W. Liller, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1992, 257pp, £19.95.

This guide shows how a keen amateur may make astronomical discoveries, using only modest equipment. Based on 20 contributions from both amateur and professional astronomers already famous for their discoveries, it describes the approaches to take in searching the skies for the unusual and unexpected.

There are all the kinds of objects an amateur may hope to find as a result of systematic searching. Visual, photographic and electronic techniques are described and instructions given on how to report discoveries.

Extensive Appendices embrace a wealth of further information of value to a would-be discoverer.

Genuine Astronaut Used Equipment

V. I. Grissom

(Gordon) Cooper

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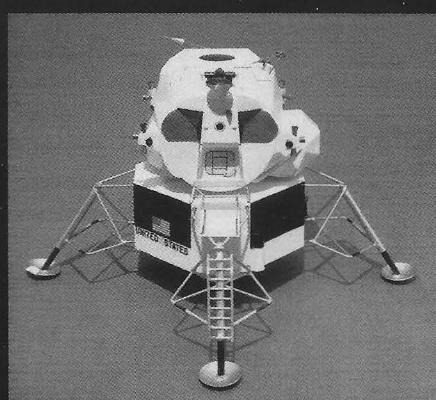
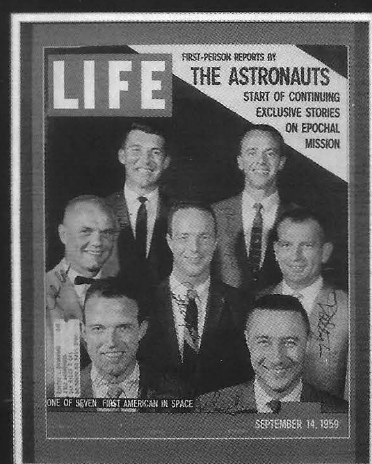


NASA/Contractor Models



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Correspondence

Meteorite

Sir, With reference to the article "Project SPACEGUARD" in the July 1993 issue of ***Spaceflight***, I can inform you, that Denmark was hit by a meteorite at 00:07 UTC on 20 July 1993.

The fireball could be seen all the way to Stavanger in the western part of Norway, and the sonic boom could be heard over a large area of east/central Jutland. The meteorite has been traced to have fallen in the water, just west of Zealand, near the town of Kalundborg.

J.K. ANDERSEN
Skagen, Denmark

SPACEGUARD Comments

Sir, Duncan Steel's excellent article on Project SPACEGUARD (in the July issue) is slightly marred by his reference to "Sir Edmund Halley". In fact Halley, though often wrongly called Sir, was never knighted. He lived before the era in which honours were given for distinction in any field, when they were still only given for service to the nation or the royal family. His contemporary Sir Isaac Newton was knighted for his service as Master of the Royal Mint, not for his distinction as a scientist.

I was also interested to see Duncan Steel's mention of the film *Meteor*, which he rightly calls scientifically appalling. The film includes an "interplanetary spacecraft" which is Skylab and direct two-way conversations take place between people on Earth and others in the spacecraft, which is supposedly millions of miles away. Oh, a Russian character arrives in the USA in a "Soviet" aircraft which is suitably plastered with red stars and whatnot - but is a Boeing 707!

RAY WARD
Sheffield, UK

Deke Slayton

Sir, I refer to the obituary notice in the August issue for Deke Slayton. I too share your sadness at the loss of one of the pioneers of manned space flight and of a man who set a shining example to us all by his unshakable faith in himself and the future with his perseverance in the face of difficulty. However, your article does him one small injustice. He was not grounded following his replacement by Scott Carpenter on the second manned Mercury orbiter mission but remained on flight status and available for selection until the time of his ASTP flight.

Set out briefly, the facts of the matter are these. Much of the chaos and confusion surrounding Slayton's replacement on the MA-7 flight stems from the suddenness of the public announcement as from anything else. Reporters at the time were at a loss to understand how a super fit astronaut could develop a heart condition from out of the blue.

Surprise may have prevailed in the outside world, but within NASA the fact that Slayton had a problem had been known for some two years.

The astronaut's physician, William Douglas, recognised the condition, idiopathic atrial fibrillation (or an occasional irregularity of a muscle at the top of the heart in layman's terms) back in August 1959 following Slayton's first ride on the centrifuge at Johnsville. Douglas decided to seek further advice before deciding on the astronaut's suitability. The chief of the Cardiology Service at the Philadelphia Navy Hospital said that the condition was "...of no consequence". The advice was the same at the Air Force School of Medicine at San Antonio, Texas. However, later, the consultant there changed his mind and wrote directly to the NASA Administrator, James Webb, suggesting that it would be better if Slayton were not assigned a flight.

There followed other rounds of medical centres. By late October 1959, Mercury Program Director Robert Gilruth was informed of a possible problem with Slayton along with the Air Force Surgeon General's Office. However, nothing further was done and Slayton was selected and began training for the MA-7 mission in November 1961.

Webb now went to America's top cardiologists - Proctor Harvey, Thomas Mattingly and Eugene Braunwall. They were unable to state categorically that Slayton's forthcoming flight would not be affected by his condition. Their recommendation was that "...if NASA had an available astronaut that did not fibrillate, then he should be used". This was a view supported by President Eisenhower's personal physician, Paul Dudley White. He said that though there was nothing diagnostically wrong which would prevent Slayton flying, it might be a wiser course of action not to add one more unknown to the many that already existed in the realm of manned space flight. Administrator Webb agreed.

So, in March 1962, came the announcement that Carpenter would replace Slayton on MA-7. It must be said that both Gilruth and Douglas disagreed with the decision.

Speculation that something was amiss and "not quite right" was increased by the announcement of the resignation of William Douglas shortly after Slayton's removal from MA-7. The two events were not connected but coincidental. This resignation had been expected within NASA for six months prior to the Slayton decision and merely marked the end of Douglas's three year secondment from the Air Force.

The other factor which caused problems in the press was the choice of Carpenter rather than Schirra, who was Slayton's back-up. Walter Williams (Operations Team Leader for Mercury) made the selection in the light of the delays and length of training for the Glenn (MA-6) flight which resulted in Carpenter being the most prepared for what was going to be basically a repeat mission to that flown a few weeks earlier.

E.T. PUGH
Essex, UK

Delta Clipper Assessment

Sir, Let me quote the major data of Delta Clipper DCY from ***Spaceflight*** (March 1993, pp.90-94):

Launch mass	471.8 t
Payload to Space Station Freedom	9.1 t
Total propellant loading	426.4 t
	(ascent use only: 414.7 t)
Dry structure mass	36.3 t

First the good news: the above data are internally consistent, meaning that DCY performs the Freedom supply mission and returns to the Earth's surface without a payload, as proposed. The propulsion system has been assumed to be of SSME quality, and thrust lift-off acceleration has been chosen to be 1.3 g_0. (Maximum thrust is about equal to 3.5 SSMEs). For the interested reader the modelling is that of a SKYNAV trajectory.

Now the bad news: our most optimistic mass model gives 56 - 58 t for the dry structure, that is 20 to 22 t more than the allocated 36.3 t - even with zero payload. DCY is fiction. A rescue mission is perhaps a possibility.

An "expendable" DCE would have about 16 t less of dry structure mass and 10 t less of (return) propellant loading, i.e.

Dry structure	40 - 42 t
(very optimistic, I feel; in reality ~ 49 t)	
Propellant loading	417 t
Launch mass	471.8 t
Payload	13 -15 t
	(in reality, perhaps 6 t only)

A DCE seems to be technically feasible with a rather small LEO payload. The launch mass/payload mass ratio (growth factor) 30 - 80 and is very sensitive to the dry structure mass fraction.

But there is no chance that a DCE would live up to the promise of a DCY and it would be of the utmost poor economy - but this is evident to any Space Cadet reading BIS publications.

I would like to thank my co-worker Alexander Hornik for his quick and competent numerical work.

Prof Dr-Ing H.O. RUPPE
Munich, Germany

In response, Mr W. Paul Blase writes:

The 36 metric ton mass cited was a projected dry weight for the DC-1, not necessarily the DC-Y. I am checking with McDonnell Douglas and will forward their latest figures for the DC-Y as soon as I receive them. The latest source that I have on hand lists the projected dry mass of the DC-Y as 104,000 lbs (47.2 metric tons) with a fully fuelled launch mass of 1,300,000 lbs (589.7 metric tons). The payload is still projected at 20,000 lbs (9 metric tons). This is still much less than the 56-58 metric tons cited by the writer. I should note that the Clipper makes extensive use of advanced composite materials to reduce weight. Indeed, it is these NASP-derived materials that make such a vehicle possible.

Re-Use of Gemini 2

Sir, Regarding the Gemini 2 discussion in the July '93 issue of ***Spaceflight***, the spacecraft was on public display in 1984 at the Air Force Museum, Wright-Patterson Air Force Base, Ohio, USA. The cockpit was open and you could clearly see the Manned Orbiting Laboratory (MOL) hatch and its fully functional locking mechanism, located between the headrests of the acceleration/ejection seats.

To accommodate the hatch, the seats had been shifted outboard to provide the space between the headrests, and the switch console, located on the frame between the two access doors, had been removed.

The heatshield was visible as was the disk of the hatch access. The shield showed the usual erosion of atmospheric re-entry, with no discernable discontinuity around the hatch disk. An accompanying display placard described the spacecraft, its history, and its successful role in the MOL program.

KEVIN G. COULOMBE
Seattle, USA

Small Space Boosters

Sir, I read with interest two of the letters concerning Skylon in the July issue of ***Spaceflight***. Both letters, by D.M. Todd and J. Franta respectively, made a similar point of using scaled down versions of the SABRE engine on the Pegasus booster. Whilst I do not wholly agree with the use of such elaborate engine technology on small boosters due to the debilitating development costs, I write to discuss the scale of benefits available from using even simple air-breathing propulsion devices to assist a small launch vehicle's ascent.

It appears that at present the majority of launch vehicle development is considering the use of high technology air-breathing propulsion units such as scramjets or liquid air-cycle engines. I agree that such work holds the key to the future of space transportation but while such work continues the booming small satellite launcher market is stuck in the rut of using only proven rocket technology.

Until the emergence of Pegasus (an unproven concept), an abyss in launcher capability had appeared between that of Scout and Delta sized vehicles. Even Pegasus only plugs a small gap in this range. However the use of ramjets and/or turbo-jets could lead to a wider ranging payload capability fleet of vehicles at low cost.

Prior to OSC's press release in December 1992 concerning their study of a turbo-jet boosted Pegasus to increase the launcher's payload (***Spaceflight***, February 1993, p.67), I completed an MSc thesis [1] which considered the effect of using a ramjet phase during the vehicle's first stage ascent. The result showed that for a vehicle with the same initial launch mass as Pegasus XL, the use of an air-breathing assisted first-stage climb could lead to a payload increase of the order of 50%.

Most launch vehicles, climbing vertically through the denser regions of the atmosphere would be unable to develop sufficient thrust from air-breathing engines to sustain flight, however the shallow trajectory climb (approximately 40°) of Pegasus provides an ideal ascent for air-breathing engines.

In identifying a suitable engine, flight experience, development cost, ease of use and manufacture and recurring cost must all be carefully considered and for this reason my study suggested a solid-fuelled ramjet. Whilst ramjets do not possess the pedigree of turbo-jets, their use on missile applications has generated a worthy flight experience. Also the simplistic design and manufacture of a solid fuel ramjet further offers commonality with the existing solid-fuelled Pegasus and a low recurring cost.

Research from around the world is suggesting a number of air-launched boosters of similar size to Pegasus, such as the German Diana, CIS Burlak and the suggestion by Aerospatiale of France. To be truly competitive in the international launch vehicle market these vehicles must cater for a wider range of payload masses within the abyss, and I suggest the use of low-technology air-breathing propulsion units is one low cost method of achieving the required increased payload capability.

D.I. WADE
Berkshire, UK

Reference

1. D.I Wade, "Enhancement of the Performance of the Pegasus Launch Vehicle Using Air-Breathing Propulsion Techniques, Cranfield Institute of Technology, September 1992.

Space Music

Sir, Following on the recent letters regarding Space related music, I wonder if fellow readers may have heard of a song entitled "Ghosts of American Astronauts"? I have no idea who sang it, but I do know it was released about a year or so after the Challenger tragedy.

The Space-Music relationship may well have come to a head during the STS-52 space shuttle mission last October, when US pop music station MTV conducted an unprecedented live interview with crewmembers of that flight. Astronaut James Wetherbee, who commanded STS-52, told the interviewer he is the drummer in a rock band made-up exclusively of NASA astronauts, while the Shuttle's pilot, astronaut Michael Baker, revealed he is an Eric Clapton fan!

HAROON QURESHI
West Midlands, UK

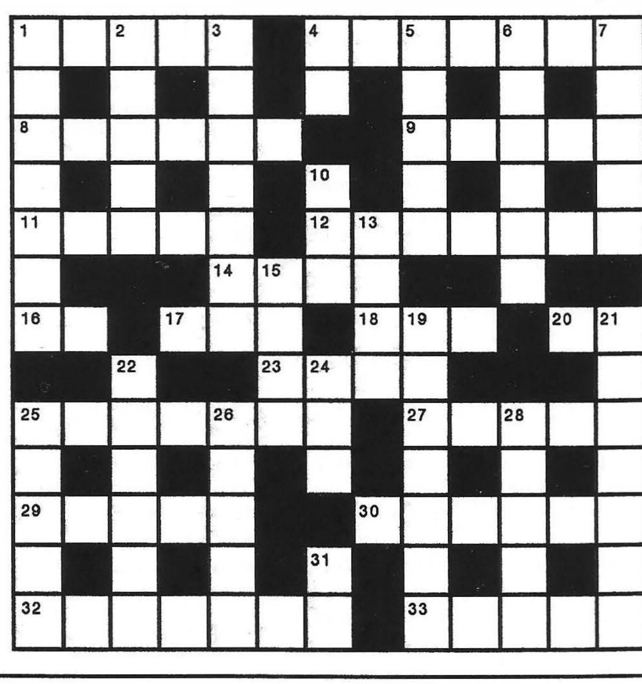
Spaceflight Crossword

No. 1

ACROSS
- 1+4 Briton in space
- 8 ——— sensing of Earth resources
- 9 Pertaining to the Moon
- 11 Soviet booster vertically overhead?
- 12 Sample return from a comet nucleus is ancient stone
- 14 Divisible by two
- 16 Refusal
- 17 Formerly ESRO
- 18 Formerly USSR
- 20 Whether
- 23 Lone boy ?
- 25 Warned by sirens
- 27 Launches
- 29 Bring upon oneself, such as debt
- 30 Set alight
- 32 Earth observation spacecraft series
- 33 Visible radiation

Solution will apper in the October issue.

DOWN
- 1 Boundary sensed by Earth-stabilised spacecraft
- 2 Thirst-quenching colour
- 3 Oscillates as the axis of a spacecraft
- 4 Includes imaginative space travel
- 5 Space launcher for maps?
- 6 Unit of time
- 7 Rocket motor with nuclear power is reshaped Raven
- 10 Natural source of metal
- 13 Expendable rockets are launched only ——
- 15 Rocket control fin
- 19 Contrary to law
- 21 Superlatively speedy
- 22 Guiding light
- 24 Not 14 across
- 25 Early UK scientific satellite series
- 26 Early US weather satellite series
- 28 Hurl
- 31 From outer space



Space Songs

Sir, About the time that you published the latest instalment in your fascinating correspondence on music and space travel, I came across a copy of a 1983 Soviet book entitled "Orbital Friendship, Songs About Cosmic Flights by Composers from the Socialist Countries". This book contains in its first section the lyrics and music for 18 Soviet songs about space travel, including "Znayete, kakim on parnem byl", a song about Yuri Gagarin referred to by Rene Demets in his letter in the July, 1993, ***Spaceflight***. Several of the other songs are also about Gagarin.

The second part of the book is a selection of songs written about the first nine Intercosmos manned flights, rendered in Russian and the language of the other country involved in each flight. There are two songs related to each flight. The well illustrated book, published by a Soviet musical publishing house, contains a total of 36 songs.

On the American side, a currently popular band, They Might Be Giants, has dedicated several tunes, and a 1992 album, "Apollo 18", to space themes. The album cover artwork incorporates space themes and proclaims the band as "Musical Ambassadors for International Space Year". They Might Be Giants' extended play CD, "the guitar" features music punctuated with bits of Moon-to-Earth conversations from Apollo 11's stay at Tranquillity Base.

CHRISTOPHER GAINOR FBIS
British Columbia, Canada

Space-Music Search

Sir, Further to the search for space-related music, I note that Hawkwind have a repertoire going back to 1970. The science fiction writer Michael Moorcock played a significant role in much of Hawkwind's early work.

The album 'In Search of Space' (1971) featured 'Master Of The Universe' and 'Children Of The Sun'. A short space fantasy book 'The Hawklog' was also provided with the original album and is now quite a collectable item.

'Doremi Fasol Latido' (1972) featured 'Space Is Deep' and 'Time We Left This World Today'. 1973 saw the album 'Bring Me The Head Of Yuri Gagarin' and Hawkwind's 1974 album 'Hall Of the Mountain Grill' had a distinct cosmic flavour. 'Spiral Galaxy 28948' featured in the 1975 'Warrior On The Edge Of Time'. In 'Quark Strangeness & Charm' (1977) the leading track 'Spirit Of The Age' theme was that of suspended animation on long space flights. More recent Hawkwind LP's such as 'Space Bandits' continue the cosmic theme.

Above all though, the classic 1972 album 'Space Ritual' typified Hawkwind's work with tracks such as 'Earth Calling', 'The Black Corridor' and a short piece about zero-G 'Upside Down'.

CLIVE TESTER
Kent, UK

Soviet Space History

Sir, I was very interested to read in the July issue of ***Spaceflight*** extracts from the CIA's National Intelligence Estimate for 1967. The prominent mention of the large space station programme seems to indicate that there is still much that we do not know of the former Soviet Union's manned space programme.

There has been mention of the large space station programme in a number of sources over the years. The earliest open sources seem to have come again from briefings by the intelligence community to NASA senior staff in the late sixties. Kenneth Gatland makes direct reference to NASA officials anticipating the launch of a large 12 man space station on the G1/N1 launcher. At the time (the early seventies) many considered the G1/N1 launcher's main task would be the deployment of a large space station [1].

Direct information from the former Soviet Union has been more limited. James Oberg made reference to a mock-up of a large space station that Sergei Korolev displayed to East European journalists in the mid-sixties [2]. There is the Leonov/Sokolov painting of a large space station (produced in the early seventies after Leonov had been reassigned from the Lunar Landing programme) [3]. The most compelling evidence to support the existence of the large station project comes from the work of Korolev when his design team were defining the spacecraft to replace Vostok. Bert Dubbelaar makes reference to the Heavy Orbital Station or HOS as part of the 1962 studies into future space systems that Korolev conducted [4].

It remains to be seen whether the HOS project ever progressed beyond paper studies. The political infighting between the Korolev Bureau, the Chelomei Bureau and Glushko may well have killed it at birth. The space officials of the former Soviet Union know the truth. Surely the time has come for a full and authoritative history of their work from a Soviet source?

I would like to say that the BIS and its publications still represent the best and most accessible forum for the general public on space matters.

JOHN DRAYCOTT
Nottingham, UK

References

1. K. Gatland, *Missiles and Rockets*, 1975.
2. J. Oberg, *Red Star in Orbit*, 1979.
3. R. Turnill, *The Observers Spaceflight Directory*, 1978.
4. B. Dubbelaar, *The Salyut Project*, 1986.

'Name the Sats' Competition

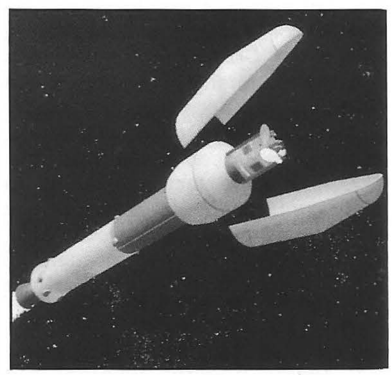
Europe's Ariane launcher will be putting many satellites into orbit between now and the end of 1994. Eight items of payload to be launched over this period of time are listed below with their names in the form of clues.

Prizes: The first three correct entries to be opened after the closing date will receive a hand-made crystal glass pint beaker engraved with the British Interplanetary Society's 'rocket' logo.

To Enter: Fill in the names, all of which appear in the 'Ariane Launch Manifest' (including the footnote) on p.305.

As a helpful guide it may be noted that the initial letters of the answers when rearranged give the name of another payload that also appears in the 'Ariane Launch Manifest'.

Clue	*Name*
Speck	....
Makes a star	....
Rattles (ana.)	....
Comes to a stop	....
Disordered saint	....
Backward dadlradilos	....
Spacecraft 'that heals'	....
Pasta without tea	....



Ariane launching one of its payloads into orbit. *Arianespace*

Title/Name ....

Address ....

....

....

Post to: The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ to arrive by first delivery on 7 October 1993.

STS-53 Landing

Sir, In the June issue of ***Spaceflight,*** Mr Ralf Hupertz discusses the STS-53 landing roll. Mr Hupertz wrote that he calculated a roll distance from NASA's published touchdown and wheelstop times and his calculations indicated that his calculated landing roll of 16,863 ft would not fit within the runway length of 15,000 ft. He wrote that this was "NASA's mistake". Actually, STS-53's measured roll distance was 10,165 ft.

Mr Hupertz's calculation appears to be based on the assumption of a *constant* rate of deceleration applied thoughout the landing roll (hence his touchdown speed divided by two). However, *variable* parameters such as wing loading and brake action also affect landing rollout distance.

Rollout figures are not always put out in time for mission reports and may not be available until mission summaries much later.

ROELOF L. SCHUILING
Florida, USA

Space Age Preconditions

Sir, In the June edition of ***Spaceflight***, Ian A. Crawford set out his theory that world government is a necessary precondition for the Space Age. He sees his idea as both utopian and necessary.

I would like to refute his assertions by arguing that the surest way to forever doom any attempt for space colonisation is to introduce a world government, even more so if it is a federal one. Let me point out some errors of his thought process.

Survival

It is true that a necessary precondition is the survival of a technological society. But what is threatening its survival? Certainly not the existence of security interests. On the contrary a perceived threat to security is the best means to focus minds on technology and its continued development. As the ending of the cold war has shown, competition (a necessary element of a capitalistic society) is essential. Dr Crawford confuses competition with anarchy. Anarchy is what is occurring in Yugoslavia and other parts of the world as a direct consequence of diverting resources away from the military. It is more than utopian to believe such conflicts would disappear with a world government. This would only happen if the world ceases to contain different cultures, and would that not be amoral?

Geopolitical Stability

It seems doubtful whether a world government could concentrate its energies on long-term projects better than nation-states. Apart from a continued existence of local conflicts as described above (and I trust Dr Crawford has not lost his common sense to argue that such conflicts will cease miraculously with an altruistic world government) he misses the economic reality of scarce resources.

Resource Allocation

Economics has to do with the allocation of scarce resources. For a world government there will always be better ways to allocate resources than to invest in an uncertain space infrastructure. It would be impossible to obtain a consensus for large space development if one could invest in such laudable projects as eradicating HIV, malaria or other diseases. Many would decry the neo-colonisation of preferring an elusive space development to improved education for the largest part of the world's population. Not to forget that cleaning the environment, and maintaining it, could take up all resources a world government may ever have at its disposal. The variety of interests in a world government which would have billions of citizens would be mind-boggling and would ensure that no space activity would ever take place.

Alternative Interpretation

The alternative view to the naivety displayed by Dr Crawford is to say that only the existence of competing nation-states will ensure the continued existence of a technological society willing to attempt long-term projects such as space research and in future space colonisation. In this context I would even argue that security reasons are the only reasons for countries or civilisations to engage in long-term planning, disregarding for a moment megalomaniac dictators. This has historically always been the case and I do not see what else could create the consensus among people necessary for long term projects.

I therefore believe that ***Spaceflight*** takes a dangerous path for space development if it helps to distract attention away from current opportunities by allowing preconditions to be aired which are at best unattainable and if not a death sentence for future space colonisation.

V. BARITSCH
London, UK

PS: I would be curious to find out what is unproductive about military development? It does not appear to be less productive/unproductive (depending on the view) than let us say the movie industry in Hollywood or parts of the sport industry. It certainly does more for technological development than the latter two industries.

Dr Ian Crawford replies:

Thank you for giving me an opportunity to respond to the letter by Vincent Baritsch. It was my intention to stimulate debate on the political preconditions to large-scale space development, and I am grateful to Mr Baritsch for participating in this debate. It is, however, unfortunate that he did not wait to read Part 2 of my article before writing his letter, as I believe many of his objections were anticipated and (to my satisfaction) resolved there. I would like to respond to some of his specific points:

1. Baritsch denies that "security interests" are a threat to technological civilisation. However, as the most serious threat to the survival of our civilisation quite obviously results from weapons of mass destruction, which have been developed by nation-states because of their perceived "security interests", I find this denial to be extraordinary.
2. I have not confused competition with anarchy. Competition is indeed valuable in many aspects of economic life, where it occurs between companies and is regulated by government. Competition between nation-states, which is anarchic in the sense that there is no effective regulatory body, is less valuable and, as we know from long and bitter experience, is actually extremely dangerous. Moreover, the claim that international competition is necessary for technological progress is quite insupportable; to pick some key inventions more or less at random, such competition played no significant role in the development of the wheel, the windmill, the steam engine, the dynamo, the radio, or (at least initially) the airplane. Technological progress long preceded the rise of the nation-state, and it will long survive the demise of that institution.
3. The points raised by Baritsch concerning "resource allocation" were discussed in detail in Part 2. To summarise briefly, there exist several reasons why a world government would wish to support a major space programme, of which the most utilitarian is the likely future demand of the world economy for extra-terrestrial raw materials.
4. The main point I wish to make was raised in the last two paragraphs of my article, and I refer Mr Baritsch back to the arguments contained therein. Will he concede that the federal constitution worked out at Philadelphia in 1787 was a political precondition to all that the United States has (in 1787 they would have said 'have') subsequently accomplished, including the landing of man on the Moon almost two hundred years later? The 'competition' argument would suggest that a North American continent divided into independent sovereign states would have achieved more than the federal continent we see today. Such an assertion seems highly unlikely to me, and may in fact be disproved by the example of South America, which has lots of 'competing' nation-states but comparatively little technological progress. On this argument I rest my case, for the concept of world federalism is merely an extension to the global scale of the same political process. Succinctly put, if American federation was a political precondition for Apollo, then it is at least possible that world federation is a political precondition for the greater challenges of solar system colonisation and, especially, of interstellar flight.

SOCIETY MEETINGS DIARY

22 September 1993 10 am - 4.30 pm

Rocketry in the 1930's

As part of the Society's Anniversary Year the History Working Group is holding a Symposium on the above topic. The 30's is seen as a cornerstone period in the development of rocket propulsion.

"Early Soviet Rocketry" by Phil Clark will cover the formation of GIRD and GDL and what the work carried out by these organisation led to.

"The development of the three inch Rocket" by Steve Pooley will be based on personal reminiscences of the period.

In addition to papers covering early rocket propulsion work in France by Christoph Rothmund and aspects of the well-publicised work in Germany, there will be a film show of archival material from the period.

Refreshments and buffet lunch will be provided.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Advance Registration is necessary.

Registration: Forms are available from the Executive Secretary. Please enclose a sae.

15 - 17 October 1993

SPACE '93

This two-day meeting commemorates the Society's Diamond Jubilee, 1933 - 1993. Please send to BIS HQ for details.

16 - 22 October 1993

44th International Astronautical Congress

The 44th International Astronautical Congress will be held in Graz, Austria, from October 16 - 22, 1993. Details of the Programme, Registration Forms, etc. are available from BIS HQ.

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.

It may occasionally happen that, for reasons outside its control, the Society has to change the date or topic of a meeting. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always recheck the scheduled meetings in the latest issue.

1 September 1993 7 pm - 8.30 pm

SOHO - A Unique ESA/NASA Mission to Survey the Sun

D.M. Simpson, Matra Marconi

The Solar Heliospheric Observatory (SOHO) is an ESA mission which forms part of the Solar Terrestrial Science programme and should contribute towards the International Solar Terrestrial Physics programme. As such it is a cornerstone of the ESA Horizon 2000 plan.

SOHO will make observations of the solar surface, corona and solar wind as well as detect any oscillations of the solar surface. Such observations will be carried out continuously from an orbital location between the Earth and the Sun, circling the L1 libration point.

Matra Marconi Space are the prime contractor for SOHO which is planned to be launched using an ATLAS 2AS.

The speaker will outline the mission, provide technical background on the design and give a prognosis of the likely results from this highly ambitious, measurement laden, mission.

6 October 1993 7 pm - 8.30 pm

Microsatellites on Micro-budgets

Prof. M. N. Sweeting

The prohibitively high cost of space projects has effectively restricted first-hand access to space to a handful of nations and international agencies. Spacecraft have grown ever larger and more complex and are also taking longer time-scales from concept to orbital operation. Advances in VLSI micro-electronics have catalysed a new species of small, low-cost yet sophisticated and highly capable 'microsatellites' - complementing, and sometimes providing an alternative to, high-cost traditional satellites.

The lecture describes the University of Surrey UoSAT microsatellite programme which reviews the key technologies, management techniques and potential applications of small satellites.

LIBRARY

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. The Library will also be open on Saturdays between 10.00 am and 1.30 pm on the following dates:

18 September 23 October
20 November 18 December

Membership cards must be produced.

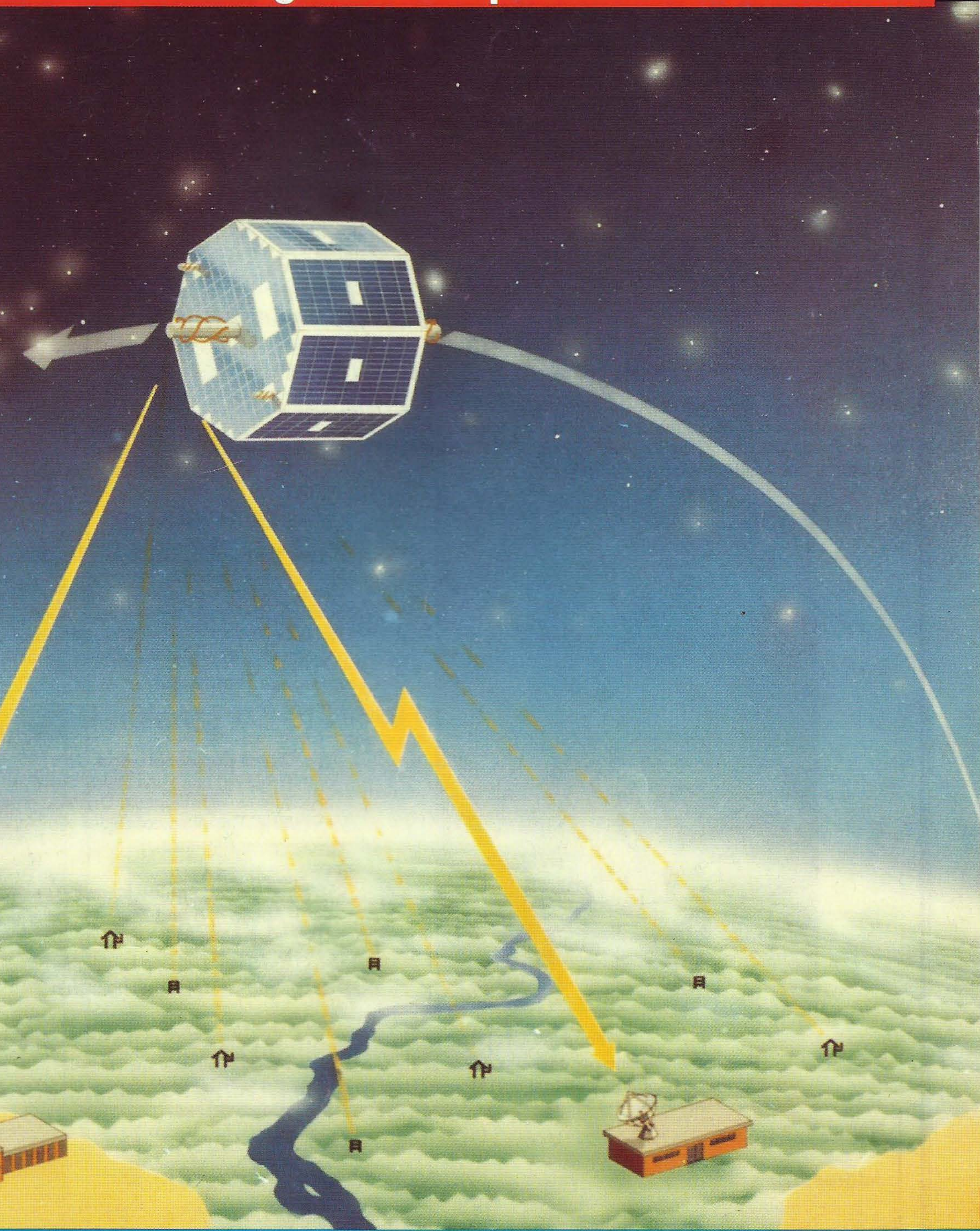
A Publication of the British Interplanetary Society October 1993 Vol. 35 No.10 US$3.50 £1.70

Spaceflight

The International Magazine of Space and Astronautics

Utilising Space

The Decade Ahead



Special Reports:

- ESA
- China
- India
- Brazil
- South Africa
- UK
- Japan
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1933 1993

SPACE '93 Welcomes Lunar Astronaut Buzz Aldrin

Programme Details p.347

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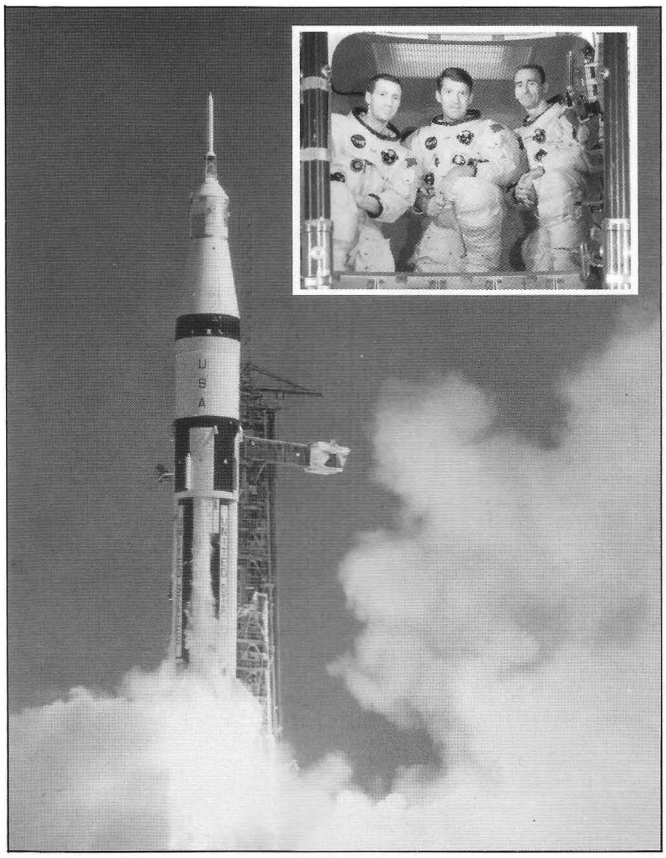


Apollo Missions 4, 5 and 7

Apollo 4 Mission: Covers the launch of the mighty Apollo/Saturn V unmanned space vehicle which reached an altitude of 11,232 miles. As Apollo 4 climbs toward this peak altitude, a camera pointed out the spacecraft window, records views of the Earth. The Service Module propelled the Command Module into reentry velocity of approximately 25,000 miles per hour. *15 mins*

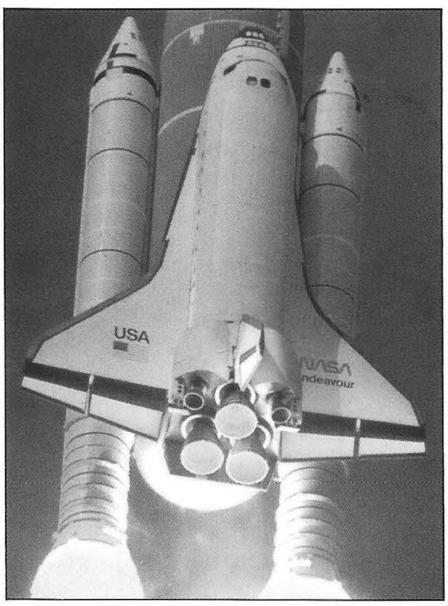
Apollo 5 Mission: Follows the successful testing of the Lunar Module, the spacecraft in which man will make his first landing on the Moon. Tracking stations around the world track its position with pinpoint accuracy as the Mission Control engineers test the many systems onboard. Lunar Module 1 - not designed to return to Earth - tumbles on through space until destroyed by the asmosphere of the Earth. *17 mins*

Flight of Apollo 7: Records life and work on the first manned flight of the Apollo series. Apollo 7 was designated to make the essential test of the Apollo spacecraft before the ambitious lunar-orbital mission could be attempted. All systems respond perfectly. The first television from space highlights the film. *14.5 mins*

Total running time 46.5 mins

Legacy of Gemini

In the perspective of a single composite mission, this documentary illustrates the major accomplishments of the Gemini two-man space flights and the significance of these flights to the Apollo Program. The film includes outstanding photography of the Earth and man in space. *28 mins*



STS-46: Mission Highlights

This features the 12th flight of Atlantis with a crew of seven. Flight objectives included the deployment of the European Recoverable Satellite (Eureca) using the Robot Arm operated by Mission Specialist Claude Nicollier and the first, though unsuccessful, launch of a Tethered Satellite. *50 mins*

STS-54: Mission Highlights

The flight of Endeavour with a crew of five features splendid scenes of the launch of the Tracking and Data Relay Satellite (TDRS) against an Earth backdrop and experiments with Biopack. Onboard crew activities include a variety of physical exercises. The video concludes with spectacular EVA and Earth shots. *50 mins*

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Spaceflight
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Front Cover: An artist's impression of a Brazilian SCD (Satélite de Coleta de Dados) in orbit. The purpose of SCD spacecraft is to collect and relay environmental data from up to 500 automatic Data Collecting Platforms. The first 'made in Brazil' satellite SCD-1 was launched by a Pegasus booster on 3 February 1993. See 'Brazil in Space', pp.338-339. *INPE*

Utilising Space

This issue looks at space plans for the 1990's and into the next century. The days when space was dominated by superpower politics have now passed and countries around the world are looking to space technology and research and opportunities for collaboration to meet their practical needs and aspirations.

A selection of recent developments are highlighted in this issue:

ESA Seeks Space

One of the important issues of the ESA Council meetings at ministerial level in Munich in 1991 and Granada in 1992 was the adaptation of the major European space programmes to the new geopolitical context. Considering the constraints imposed by reduced state budgets and in the perspective of new forms of international cooperation that so far had seemed impossible, it was natural to examine whether a broader cooperation could reduce development risks, procurement expenditures and operational costs of space programmes. Potential partners for such new forms of cooperation were identified to be the USA, Russia and Japan.

The New Geopolitical Environment

While the Western European countries have a long-standing record of cooperation with the USA and Japan in many domains, cooperation with Russia in high-technology areas is a relatively new experience. Cooperation between scientists from both sides has always existed and the Hermes programme itself, long before Munich and Granada, had established first contacts with the then Soviet Union, but in the cold war climate these contacts remained symbolic and did not result in substantial joint activities.

The ESA/USSR agreement on space cooperation signed in April 1990 marked a change. Joint working groups were established to define fields of possible concrete cooperation, one of them being manned space transportation systems. The ESA representatives to this working group were from the Hermes programme.

The ESA Council at ministerial level in Munich in November 1991 resulted in a further step. The Ministers instructed the ESA Director General to investigate cost reductions of the space infrastructure programmes though cooperation. This allowed the Hermes programme to award about 30 study contracts with research institutes and industrial companies in Russia.

The major hurdle for cooperation was a lack of mutual knowledge of each other's space programmes, organisational structures, and working methods. The 30 Hermes study contracts alleviated the problem. Since no space agency existed at that time in Russia, the working group comprised, on the Russian side, of representatives from Glavkosmos and from the major Russian space research institutes and scientific-industrial organisations (so-called NPO's).

Space Transportation for Cargo and Crew

The Granada Council of November 1992 opened the door to cooperation even wider. A three-year re-orientation phase was introduced into the Hermes programme during which the possibilities for joint development of crew and cargo transport vehicles will be investigated in depth.

For this purpose and as a first step, three joint working groups in the field of crew and cargo space transport have been created between ESA and RKA, the Russian Space Agency that had been established in the meantime by the Russian government: the STS-1 group to cover system aspects, STS-2 for technological aspects, STS-3 for robotic means and space suits for extra-vehicular activity. In parallel, the Columbus programme also set up two working groups, SSM-1 and SSM-2, to study possible joint activities in the field of space stations and of crewed missions.

More specifically, the STS-1 group will investigate the participation of ESA, as a first step, in the modernisation of the present Russian space transport vehicles (Soyuz for crew and Progress for cargo), which Russia envisages within the framework of the new Mir-2 space station. The group will also examine the possibilities, as a second step, for joint or complementary development and utilisation by ESA and RKA of the new crew and cargo vehicles intended to replace these modernised Soyuz and Progress vehicles around 2005. The possibility of using Ariane-5 for launching these vehicles is considered by ESA

Eastern Horizons

After the collapse of the Soviet Union and the creation of the Community of Independent States, new horizons opened up for cooperation between two main Russian Centres and the present contacts of ESA.

TsAGI

The Zhukovsky Central Institute for Aerothermodynamics (TsAGI) is one of the largest centres of aeronautical science in the world. It was in particular a major force in the testing of the reusable orbiter Buran. 12,000 people work in this institute and half of them are scientists carrying out a high standard of research effort, both fundamental and applied. TsAGI is well known for its experimental facilities for aerothermodynamics and structural testing.

But TsAGI also has a very interesting competence in the area of automatic control and simulators. TsAGI was involved in parallel research investigations during the development of the Buran entry flight control system and in the critical evaluation of the design of the prime contractor, NPO Molniya.

TsAGI has expertise in the area of flight mechanics and automatic control: mathematical modelling, control design, man-in-the-loop simulations and refinement of control design based on the comments of pilots using simulators ranging from those that are PC-based for low cost investigations, up to six degrees of freedom motion-based simulators.

CPK

The Gagarin Cosmonauts Preparation Centre (CPK, also known as Star City) has been and is responsible for the training of all astronauts since Gagarin. To improve the quality of the training, several Research and Development divisions have been created, in which new training techniques are investigated, as well as Man-Machine-Interface and advanced control strategies for their influence on the pilot.

An edited extract of 'Eastern Horizons' by F. Ankersen, N. Buc and D. Paris in Preparing for the Future, ESA's Technology Programme Quarterly, June 1993, p.19.

Cooperation with Russia

as a cornerstone for cooperative activities.

Key Technologies

STS-2, the technology group, will investigate the possibilities for joint study and development of key technologies for the projects defined by the STS-1 group. Typical technologies are aerodynamics and thermodynamics, thermal protection, environmental control and life support, avionics, and power generation.

Space Suit and Robotic Arm

STS-3 is looking at the EVA Suit 2000, the concept of which has been developed over the last two years by Dornier and NPO Zvezda. The objective is now to develop jointly such a suit making use of existing industrial experience and of testing and training facilities.

ERA, the External Robotic Arm, is a further subject of interest for STS-3. ERA is a derivative of the ESA Hermes Robotic Arm (HERA) study and it is intended to develop such a system, compatible with the EVA Suit 2000, and to work in conjunction with RKA and Russian industry to ensure the utilisation of the ERA and of the EVA Suit 2000 on the space station Mir-2 by Russian and ESA astronauts.

New Hermes Contracts to Russia

In order to have a sound basis for their investigations, the three working groups will jointly propose and supervise technical studies which ESA and RKA intend to award to institutes and industrial companies on both sides. In the case of the work of the groups STS-2 and STS-3, these activities continue and complement the studies already performed or started under the contracts awarded by the Hermes programme in Russia in the initial cooperation scheme prior to the establishment of the three STSs working groups. The new contracts with Russia will be awarded by the Hermes programme team in Toulouse as well as through West-European main contractor firms. In both cases, the payments will be performed in ECUs directly from ESA to the Russian contractors and sub-contractors.

Follow-on Agreement

The activities of the working groups are covered by a preliminary agreement, formally reached by an exchange of letters between the ESA and RKA Directors General, for a six-month period extending to end of October 1993. During this period, the working groups will work out the technical and programmatic parts of the formal agreement between ESA and RKA on the cooperation in space transport and infrastructure systems until the year 1995. This agreement is expected to be signed this Autumn.

The selection of space transport system concepts to be examined further will be made by the STS-1 system group around Spring 1994. This selection will also orient the further work of the STS-2 technology group. The formal decision on the cooperative development and later joint utilisation of the selected concepts is expected to be made in 1995.

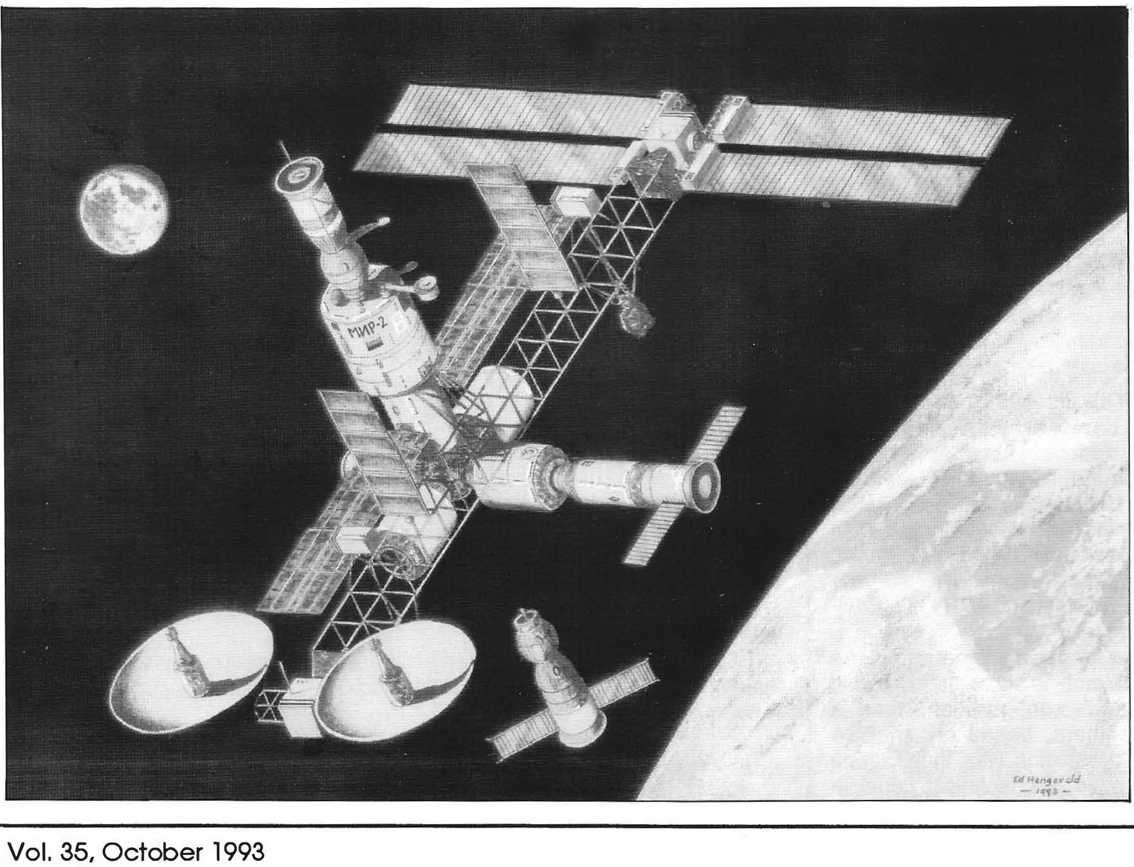
An edited version of the article 'Cooperation with Russia in the Hermes Programme' by G. Valentiny and D. Isakeit in Reaching for the Skies, No. 8, June 1993, ESA Publications Division.

Mir-2 Takes Shape

According to recent reports on Russian Television, the manufacture of the core module of the orbital Mir-2 station has already started. This first element is planned for launch in 1996. Five modules rigged to the central element of a long truss will constitute the nucleus of the station. Two large solar batteries will be rigged to one end of this truss, while to the other two parabolic mirrors will be used to concentrate solar radiation. One of the short modules will be equipped with an ordinary docking unit to receive manned Soyuz ships and automated Progress cargo. Other modules will be equipped with a unit for docking with the NASA space shuttle and (perhaps) that of Russia.

Theo Pirard

Artist's impression of the planned Russian space station Mir-2. *Ed Hengeveld*



Space Transportation

Ariane 5: Hermes Reoriented:

Two ESA Council meetings at ministerial level, one in Munich in November 1991 and the other one year later in Granada, have been devoted to the orientation of long-term cooperative European space programmes in the light of new constraints and opportunities. The result is laid out in a set of ministerial Council resolutions, commonly referred to as the 'Granada resolutions'. In the field of space transportation, these resolutions may be summarised as follows: Confirmation of Ariane-5, reorientation of Hermes and initiation of FESTIP, the Future European Space Transportation Investigation Programme.

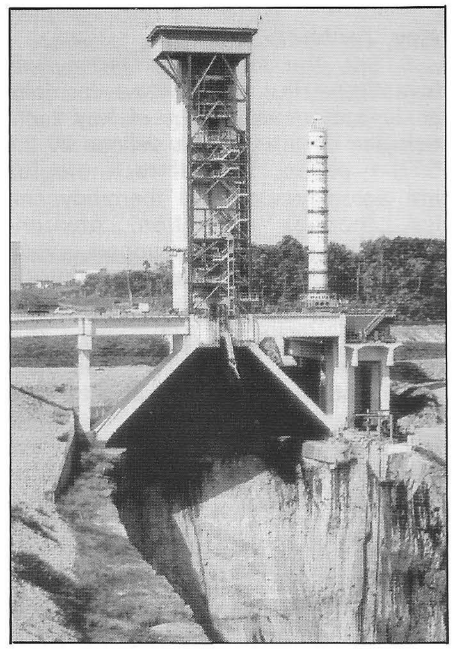
Ariane-5

Formally speaking, the Ariane-5 programme itself did not require any further decision in Granada, since the whole development programme had already been approved at the ministerial Council of The Hague in 1987. In Granada, the European ministers reconfirmed the strategic character of access to space for Europe as provided by Ariane and its Guiana launch base, and reaffirmed the principles of European space launcher policy in the light of the new international scene. These principles include the preferential use of Ariane by ESA Member States for their own missions and those of European and international organisations in which they participate, the use of Ariane-5 in future programmes of international cooperation, the world-wide marketing of Ariane launches, and the desire to reach agreements with other space-faring nations, with the political support of the European Community, on the adherence to basic rules on fair competition in the launcher market.

The Airane-5 development programme has been progressing towards the first qualification flight in October 1995. The first static firing last February in Kourou of a P230 solid booster, equipped with a reinforced casing, a configuration called 'the battleship version' by insiders, has been a success. Testing of the cryogenic central stage in its battleship version is planned for early 1994, and in the flight configuration in late 1994.

The first two Ariane-5 flights, called '501' and '502' will be qualification flights, and are therefore under ESA responsibility. They are scheduled for October 1995 and April 1996. Both will carry ESA and other satellites: Cluster, an ESA satellite for solar studies on 501; Artemis, a pre-operational forerunner of ESA's Data-Relay Satellites System (DRS) and the small radio-amateur satellite Amsat-P3D on 502. A decision on a fourth 'passenger' is still awaited. After the 502 flight, Ariane-5 will be turned over to Arianespace for commercial exploitation, the first commercial flight being presently planned for Summer 1996. Arianespace is expected to order the launch vehicle for this flight from European industry in October of this year. In parallel, Arianespace will start marketing Ariane-5 launch services.

An edited version of the article by J. Feustel-Büechl, Director Space Transportation Systems, in Reaching for the Skies, No.8, June 1993, ESA Publications Division.



Arrival of Ariane 5's P230 booster on the launch pad for the booster's first full-scale ground firing on 16 February 1993. *ESA*

Hermes: Reoriented Programme

Concerning Hermes, the decision was taken to investigate potential openings for expanded cooperation in the field of crew and cargo transport systems with

Assured Crew Return Vehicle

While preparing the development of the permanently manned International Space Station Freedom, NASA recognised there was a need for an assured crew return capability. After performing trade-offs, NASA established that an attached vehicle, able to return the crew to Earth in case of an emergency evacuation, is the preferred solution. Primary design reference missions that have been defined for this 'life-boat', formally called the Assured Crew Return Vehicle (ACRV), are return of an ill or injured astronaut; return of the entire crew should the Space Station Freedom become uninhabitable; return of the entire crew should the Space Shuttle resupply flights be interrupted.

Initial Steps

The ESA Council, held at Ministerial level in Munich in 1991, encouraged cooperation between ESA and other space-faring nations. Accordingly ESA recognised, in February 1992, that the ACRV could be an item for cooperation between ESA and NASA. ESA's contribution could consist of the development, delivery and support, over the 30-year lifetime of the system, of ACRV flight vehicles.

ESA made a first assessment of such a system, from March to June 1992, based first on a NASA configuration, then a second assessment, based on an ESA concept. The conclusion was that Europe does indeed have the technical capabilities for developing and supporting the operation of an ACRV, and that consequently the concept definition work should be pursued.

Phase A Study

During the summer of 1992, tender activities for a Phase A study were initiated and in October 1992 ESA kicked-off two parallel studies, one with Alenia Spazio SpA as prime contractor, the other with Aerospatiale.

The main results of the Phase-A studies were presented in March 1993 as follows:

- a Viking or Apollo type capsule could satisfy the requirements. The aerothermal environment would be similar for both types of vehicle, though a Viking capsule would, for the same overall geometry, have more flexibility for reaching the required landing sites (Texas, Florida, Western and Eastern Australia);
- due to launcher diameter constraints the ACRV has to be made up of two modules. A resource module holding the propulsion subsystem would be separated from the capsule just before reentry and would then burn up. The other, the reentry capsule, would carry the crew and is equipped with the necessary life-support equipment and with the landing system;
- the landing system is made of parachutes (similar to Apollo), of retro-rockets and shock absorbing devices to reduce the impact shock;
- ablative material would be used for thermal protection;
- the overall mass of the ACRV would be in the order of 8.6 tonnes at the time of separation from the Space Station -

Plans of ESA

FESTIP Initiated

the USA and Russia, within the new international political landscape. Hermes engineers had often thought about worldwide cooperation in the field of Hermes-type manned space vehicles and contacts with the Soviet Union had started long before the Europeanisation of the Hermes programme. For obvious reasons of political advisability and technological competition such a cooperation had not proved feasible during the cold war.

It therefore became mandatory to re-examine the matter of the Hermes configuration, which had already been defined at the completion of phase 1 of the Hermes development programme. The Granada Council decided upon a three-year long re-orientation phase during which various technical concepts and cooperative schemes will be investigated in detail. In parallel, technological work will continue in key areas. In 1995 the ESA Member States will decide on the final orientation and financial organisation of the Hermes programme based on the technical, programmatic and political results achieved by then.

The re-oriented Hermes programme consists of the following activities:

- system studies, primarily directed towards the definition of a crew and cargo transport vehicle to be developed in cooperation with Russia;
- the further development of major critical technologies;
- the definition study phase (so-called B phase) for an Assured Crew Return Vehicle (ACRV), a life-boat for a space station, and an element of cooperation with the USA;
- definition studies and pre-development of the 'Servicing Elements', a set of four versatile elements envisaged for the visit, resupply and maintenance in a wide range of possible space station concepts, also in cooperation with the USA as well as with Russia. The four elements are: the Automated Transfer Vehicle (ATV), the Automated Rendezvous and Capture (ARC) system, which is a prerequisite for automatic proximity operations and rendezvous and soft docking techniques between space vehicles and space stations, the Eternal Robotic Arm (ERA), and the Extra-Vehicular Activity Suit (EVA Suit 2000).

The budget for the Hermes programme between January 1993 and December 1995 is 567 million ECU. More than 300 million ECU will be devoted to system and technology activities. These activities will make maximum use of past investments in the Hermes development programme and will consolidate and broaden the know-how base already acquired in European institutes and industrial companies participating in the Hermes programme. It is very important for Europe to develop its know-how in system aspects and in the technological key areas of crew and cargo space transport systems in order to be accepted as a cooperative partner on an equal footing, and to be prepared, should cooperation turn

out not to be feasible, to master later all critical aspects by its own means.

FESTIP

FESTIP, the Future European Space Transportation Investigation Programme, is a further outcome of the Granada Council meeting. Its objective is to study system designs and technologies aimed at improving cost efficiency, reliability and other important parameters of future space transportation systems. The three-year study and technology programme starting this year will itself be the first step for a more intensive programme to follow after 1995.

Conclusion

The past two years have been difficult for industrial firms and research institutes involved in European space programmes, as the constantly evolving international political scene and budget constrains have required constant replanning. This process took place in a situation characterised by drastic reductions in public budgets, especially in the defence sector and the institutes and companies that were hit by these reductions have often been the same as those that participate in international space cooperation.

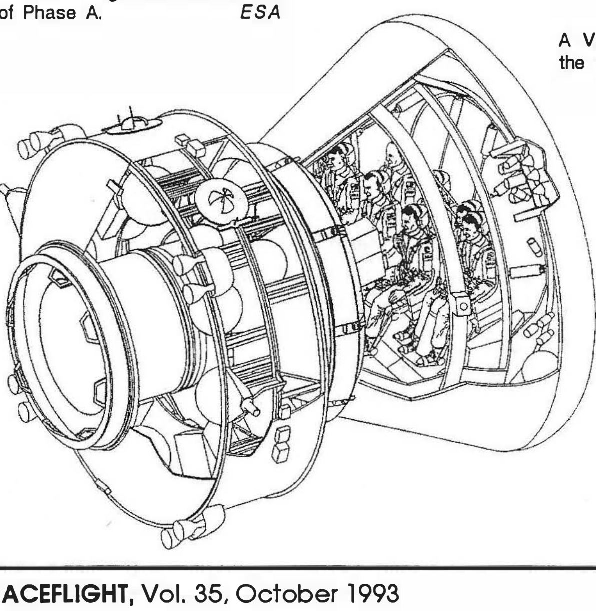
6.7 t for the capsule and 1.9 t for the resource module;

- to ensure the high level of availability, maintenance should be carried out every three months when the resupply of the Space Station by the Shuttle takes place.

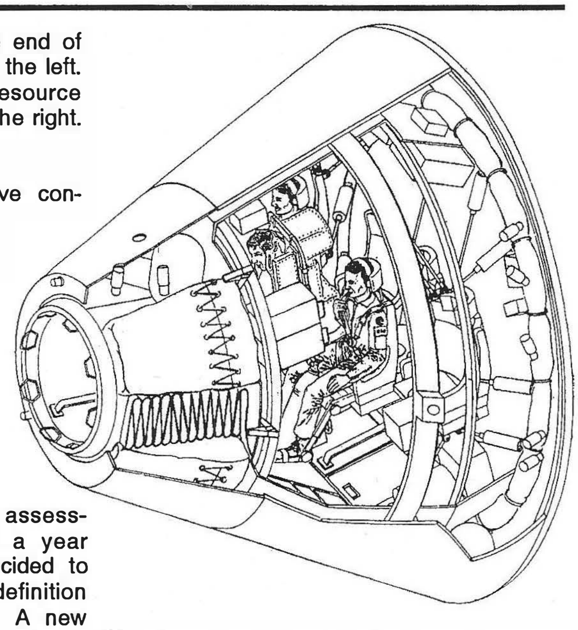
The overall configuration at the end of Phase A is shown in the figure on the left. A Viking capsule without the resource module is shown in the figure on the right.

Phase B by 1995

Since the phase-A results have confirmed the initial assessment carried out a year ago, ESA has decided to proceed with a definition phase (phase B). A new tender action has therefore been initiated. Phase B is planned to start in October 1993, and to be completed in 1995. During this phase, the detailed definition of the system and subsystems will be performed with cost estimates to be available in 1995 to support the programme proposal to the ESA Council planned for 1995.



Overall configuration at the end of Phase A. *ESA*



A Viking type capsule without the resource module. *ESA*

An edited version of "The Assured Crew Return Vehicle (ACRV)" by M. Nérault in Reaching for the Skies, No. 8, June 1993, ESA Publications Division.

ESA's Space Infrastructure

Four Projects for Space Station

In approving the reoriented Hermes programme at Granada in November 1992, the ESA Ministerial Council gave the go-ahead to three years of phase B and pre-development activities for four closely related building blocks of the space infrastructure, name: the automated Rendezvous and Capture Demonstrations; the Automated Transfer Vehicle; the EVA Suit 2000; and the External Robotic Arm. These projects are all associated with the external servicing of, and support to, space infrastructures such as the Space Station Freedom and the Mir complex.

ARC Demonstration in 1997

The Automated Rendezvous and Capture (ARC) demonstration is a joint ESA/NASA venture to demonstrate the ability of unmanned spacecraft to navigate automatically to, and dock with, another craft.

The launch is planned of a target spacecraft (an Astrospas) and a chaser spacecraft (a Minispas) from the NASA Space Shuttle. Following deployment from the Shuttle the two spacecraft will separate and then perform a series of manoeuvres and approach trajectories under both ESA and NASA sensors and navigation computers, culminating in the docking of the two satellites for retrieval by the Orbiter.

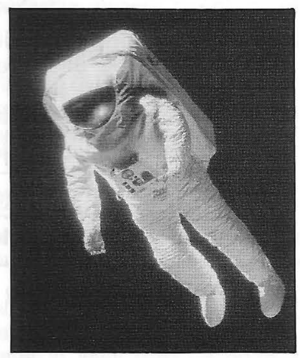
Ground simulations of the mission will be performed, and the actual results in orbit will be compared with predicted results in order to validate the ground tools for application to future projects. The flight is planned for August 1997.

An edited version of 'The ESA servicing elements for manned space flights' by A. Thirkettle in Reaching for the Skies, No.8, June 1993, ESA Publications Division.

ATV for Year 2000

The Automated Transfer Vehicle (ATV) is a versatile, rugged, expendable upper stage designed for Ariane-5, and can transport some 16 tons of cargo to low Earth orbit destinations such as Space Station Freedom. Joint technical activities with NASA have been initiated to evaluate the feasibility and attractiveness of the ATV for providing the routine delivery of logistics flights to the Space Station, and a series of reference missions is being developed with NASA, carrying potential carriers such as pressurised modules, cryogenic fuel containers, unpressurised equipment, crew rescue vehicles and propellant modules to the station. The ATV is about 4 m in diameter, 3 m high and weighs about 5 tons including about 3 tons of fuel. The ATV will navigate automatically to the station using the equipment and strategies developed in the ARC project. Current planning foresees an opera-

EVA Space Suit



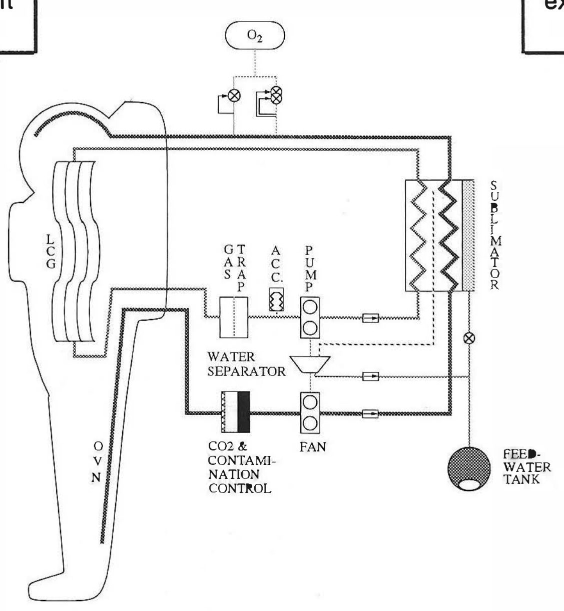
A space suit is necessary for an astronaut to perform extravehicular activities (EVAs) outside the protective environment of his mothercraft, with very limited dependency on the mothercraft. The space suit has therefore to be a small spacecraft on its own and one that fits snugly around the astronaut's body in order to allow him to work efficiently. In particular the space suit has to provide all means of sustaining the life of the astronaut. This task is performed by the life support system which is located in the backpack on the space suit. Due to the stringent limitations in volume and mass, compactness and a high degree of integration play an important role in the design of the EVA Life Support System.

Configuration of the EVA Life Support System

In order to ensure that the space suit provides the astronaut with a sufficient degree of mobility its internal pressure is limited. To achieve the required reduction, the atmosphere in the suit consists of pure oxygen.

During EVA the astronaut has to perform tasks calling for moderate to heavy physical activities. For example the average activity during EVA is comparable to cycling at about 15 km/h while peak activities are equivalent to (manual) wood cutting. The heat generated by the astronaut cannot be removed by gas cooling alone; in the confined volume of the space suit this would require excessive airspeeds, intolerable for the astronaut and resulting in excessive system mass. In the space suit the astronaut is cooled by a liquid cooling garment (LCG) which covers the whole body, except for hands, feet and face. Water is circulated through small plastic tubes in the cooling garment and is routed to the heat sink of the space suit.

Configuration of EVA Life Support System. *ESA*



The heat sink is peculiar to the space suit. Radiators - as used on other spacecraft - would require a size of more than 2 m². On the space suit there is not enough space to install such bulky items: its heat sink is a compact ice sublimator integrated with a three-way heat exchanger for cooling the water and oxygen loops. for the cooling during one EVA sortie 4.6 litres of water have to be carried along in a dedicated feedwater tank.

The water used in the cooling system is circulated by a small centrifugal pump. In order to save mass and volume the pump is integrated with a fan and a

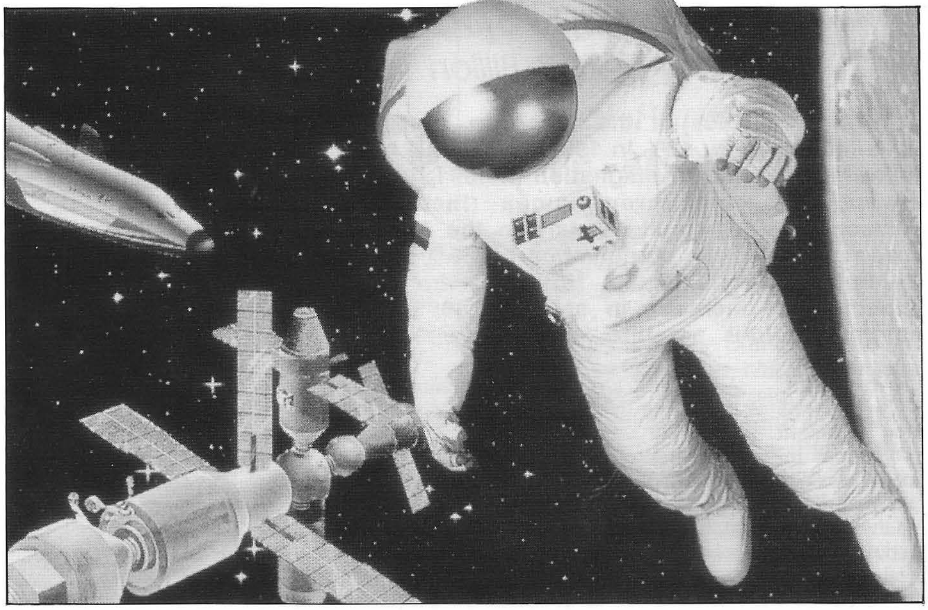
Plans

Work

tional availability by 2000 following a qualification demonstration flight in 1999.

EVA Suit for Mir-2

The EVA Suit 2000 project addresses the development of an advanced autonomous anthropometric suit system to be used in the construction and servicing of the Mir-2 space station. It is a joint development with the Russian Space Agency in which the management and system engineering and avionics subsystems are led by European contractors, and the suit enclosure and backpack (containing the life support equipment) is led by Russian contractors. The suit will be capable of being left on orbit between uses, necessitating the capability for on-orbit maintenance. The system will be used by astronauts for the inspection, repair and/or replacement of failed or worn components of the station. It is foreseen that the system would be launched before 2000 on a Russian vehicle to Mir-2.



Scenario of ESA's space infrastructure plans. *ESA*

Robotic Arm for Mir-2

The External Robotic Arm (ERA) is a derivative of the Hermes Robot Arm and has the purpose of performing routine, planned, external servicing of Mir-2, both autonomously and in conjunction with the EVA Suit 2000. The arm is a European development and a joint ESA/Russian Space Agency team is looking at the mission requirements, design options and development/utilising planning in order to determine the optimum arm design. It is currently expected that the arm would be launched between 1998 and 2000 on a Russian vehicle to Mir-2.

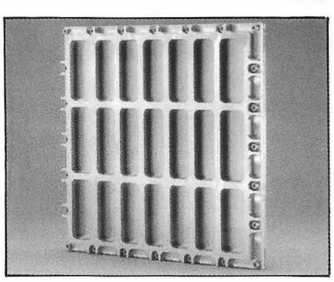
water separator into one unit driven by a single motor.

The suit is ventilated by a circulating flow of oxygen at controlled temperature and humidity. The flow enters the suit at the helmet and is sucked out at the astronaut's extremities into the Oxygen Ventilation Network (OVN) connected to the Life Support System. Thereafter, carbon dioxide and trace contaminants are removed in a cartridge containing lithium hydroxide and activated charcoal.

Driven by the fan, the oxygen flow passes over the condensing heat exchanger and returns to the helmet. The condensate is separated from the gas in a centrifugal water separator and is stored in the feedwater tank. CO_2 levels in the suit are monitored by two CO_2 sensors located in the oxygen loop.

There is redundancy in the most critical assemblies in the Life Support System, even in the limited volume available. Redundancy is implemented for pressure regulators, the integrated fan pump separator, CO_2 sensing and total pressure indicators, and in most electronics. In case of a second failure, which would render the Life Support System inoperable, an open loop oxygen flow is activated. It can ventilate the suit and cool the astronaut for 30 minutes allowing him to return safely to his mothercraft.

View of sublimator breadboard. *ESA*



Packaging

The Life Support System is packaged into a backpack located in the back entry door of the space suit. As a fire safety precaution all electronic boxes and batteries are located in vacuum. The remaining components are located in the oxygen atmosphere.

Technology Developments

During the preliminary system definition studies several assemblies were identified as involving critical technologies and were selected for breadboarding. The sublimator breadboard is shown in the picture on the lower left.

Further Development - EVA Suit 2000

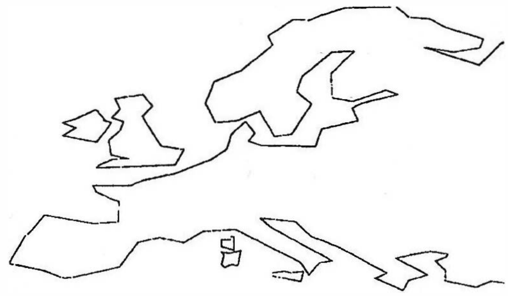
In line with the changing scope of the Hermes Programme the development of the space suit is now being pursued as a joint activity with the Russian Space Agency. Zvezda, the company which developed all space suits in the former USSR, has joined the industrial consortium which is led by Dornier bringing to it their long standing experience in this field. The first use of the Euro-Russian 'EVA SUIT 2000' will be in the Mir 2 space station. It is a main goal, however, to develop a space suit system with sufficient flexibility to allow it to be used from a wide range of mothercraft including Buran and a possible future Euro-Russian manned space transportation system and space station. For the Life Support System, this implies that the interfaces to the mothercraft have to be simplified to the highest extent possible.

A helmet ventilation testbed including a breathing mannequin used to study the basic parameters influencing carbon dioxide built-up in the helmet and visor fogging. *ESA*

An edited version of 'Example of a Life Support System - The Space Suit' by J. Witt and E. Myrseth in Preparing for the Future, ESA's Technology Programme Quarterly, June 1993, p.1.

European Space Industry

A Nearly ECU 3 Billion Industry in 1992



Consolidated sales of the European space industry are estimated to have increased by 16% in 1992 to ECU 2.9 billion. This dramatic growth, following a period of stagnation in 1991, is related to the completion of several important programmes (including Eutelsat-2, Hispasat, Telecom-2), and simultaneously to the first deliveries for the Ariane-5 programme and the continuation of R&D on ESA programmes (Artemis, Columbus APM, Envisat). However, the European space industry is expected to decrease in sales in 1993 as both ESA spending on orbital infrastructure and the European communications satellite market level-off.

Introduction

Development of the space industry in Europe is recent. It was not until the early 1980s that the space market truly developed outside the realm of the space agencies. This late start led to very strong growth in the civil commercial communications market. Military applications also emerged in the 80s, essentially in communications, but also in the R&D phase of an Earth observation system. The commercial launch business began during this period and developed very rapidly, thanks essentially to the communications satellite market, both in Europe and for export, to countries including the USA.

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Sales in 1991

The European space industry had estimated sales (excluding sales between European aerospace companies) of ECU 2.5 billion in 1991, or slightly more than a tenth of US space sales (ECU 21.6 billion), reflecting Europe's smaller domestic market. This sales figure comprises three kinds of production:

- R&D and infrastructure accounting for ECU 1.1 billion (development of Ariane-5, R&D on Hermes and Columbus, basic activities of ESA) which is entirely funded by space agency budgets;
- The launch vehicle production business, which supplies products to Arianespace (Ariane-4) and accounted for ECU 550 million, including more than 50% for export;
- The satellite production business with estimated value of ECU 850 million, including ECU 750 million in sales to the European domestic market alone and ECU 100 million for export. The satellite production business is broken down relatively evenly between two groups of applications: Earth observation and science (53%), and communications/broadcasting (47%).

The European commercial market, consisting essentially of communications satellites and their launches, has grown in recent years to become comparable with the US commercial market. It is estimated at ECU 800 million for 1991, representing sales to telecommunications operators, to Arianespace, and to other space manufacturers outside Europe.

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Satellite Communications in Western Europe: Today's Dominant Space Applications

The Western European market for fixed satellite communications is estimated at ECU 1.660 billion for 1991 and is equivalent to over half the value of the US market, reflecting both the comparison of transponder populations and the generally higher cost of European satellite equipment and services.

The market's value fluctuates considerably from year to year, depending on the number of launches, payment schedules and other factors. The four geostationary satellites launched in 1991 for European communications operators totalled an estimated ECU 500 million, including the cost of launches and ground control.

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The European Space Industry Is Highly Export-Oriented

At ECU 380 million, the export market accounted for about 15% of European space industry sales in 1991. Although European space production is around ten times smaller than in the United States, the importance of export markets is greater for Europe. This market remains very highly dependent on the success of one company, Arianespace, in the increasingly competitive commercial launch market. For 1991, the production of Ariane launch vehicles for non-European customers is estimated to represent around 80% of total export of the European space industry. In that year Arianespace launched 9 communications satellites, including 5 for non-European customers or international organisations (Intelsat, Inmarsat). Similarly in 1992, 7 of the 10 communications satellites launched were for export. This continues to be the case in 1993.

With regards to satellite prime contractorship, export performance of European manufacturers has been poor over the past years. There has been more than a two-year gap in the granting of Turksat prime contractorship to Aerospatiale in December 1990 and that of Arabsat second-generation to the same company in early 1993 (***Spaceflight***, August 1993, p.281).

With a few important exceptions (NiH_2 batteries, EHF and C-band SSPAs, EHF TWTAs), European manufacturers generally control the European market for space equipment. The export performance of European equipment manufacturers is best for TWTAs and communications repeaters. An appreciable fraction of the world market for TWTAs is controlled by three European specialist companies (Thomson CSF, AEG, and ANT) which even gained access to US commercial or military programmes (including DirecTV, NStar, Milstar, Asiasat-2, Intelsat-7). Two companies, Alcatel Espace and Matra Marconi Space UK are becoming established suppliers of communications repeaters through teaming arrangements with US and European prime contractors. They are providing communications payload equipment and/or assembly, integration, and test respectively for Turksat, Arabsat-2, Intelsat-7, Amos, and Koreasat, Inmarsat-3, Intelsat-8.

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Restructuring in the European Space Industry

The European space industry in characterised by a large number of companies (about 55) supplying flight hardware and R&D works in space technology. Companies which are exclusively service-oriented (maintenance, software, engineering, simulation and tests), exclusively ground terminal manufacturers, and materials and electronics suppliers are not included in that total.

Two categories emerge from these 55 companies:

- the prime contractors of complete spacecraft or launch vehicles, responsible at system level;
- the equipment manufacturers, which deliver units of hardware to the prime contractors and/or to other equipment manufacturers.

A rather clear distinction exists between satellite and in-orbit infrastructure manufacturers on one hand, and launch vehicle manufacturers on the other hand. There is a greater concentration in the launcher business than in the satellite business with about ten companies operative almost exclusively in this market, excluding system prime contractors such as Aerospatiale, DASA, SEP, MMS.

Towards a Duopoly in Satellite Prime Contractorship and Concentration in Space Equipment Manufacturing

Three intra-European industrial mergers have been conducted in the space industry since 1989, leading to the formation of integrated legal entities at the level of prime contractorship:

- DASA in Germany (1989) consolidated MBB, Dornier, and Telefunken System Technik;
- Alenia in Italy (year-end 1990) merged Aeritalia and Selenia and established a Space Division, including Alenia Spazio and various subsidiaries (Laben, Space Controls Alenia Honeywell, Space Software Italia, Proel Technologies);
- Matra Marconi Space (MMS), early 1991, combined the space business of Matra and GEC-Marconi.

Competing with MMS, a second industrial entity has been created, grouping together Aerospatiale, Alcatel Espace, Alenia, and DASA into Space Systems/Loral in 1992. The four European companies, called Alliance, now have a 49% holding in the American space manufacturer. The group, which

draws together the capabilities and expertise of the five companies on each side of the Atlantic, is operating on the world market under the trademark of Space Systems/Alliance.

Restructuring and consolidating operations have been undertaken in preparation for the Single Market. However they are also related to changes in the space market itself, which has become increasingly competitive and has turned more toward commercial applications, where European prime contractors are now challenging American suppliers.

At the equipment manufacturers level, significant industrial operations have also taken place in recent years:

- In 1990, the FIAT group combined the space activity of its companies (BPD Difesa e Spazio, FIAT Spazio) into Gilardini;
- Saab Ericsson Space (early 1992) merged the space activities of Saab Scania and Ericsson;
- Early in 1993, Sextant Avionique (France) acquired CIR, a Swiss manufacturer of space equipment.

Ranking of the Top European Space Companies

The lion's share of total space sales are made by a handful of companies. In 1992, the five leading companies surveyed accounted for 74% of all space sales, up from 57% in 1984.

Apart from Arianespace, which serves as an interface between industry and the market, and whose sales have fluctuated sharply in recent years with the halting and resumption of launches, the European companies involved in space production can be broken down into three main categories.

Companies	1992 Space Sales	Growth over 1991
	ECU million	%
DASA	945	+28.5
Aerospatiale	876	+24.4
MMS	811.5	+17.8
SEP	506	+17.3
Alenia Group	478	+40.2
including Alenia Spazio	409	+29.8
Alcatel Espace	255.6	+8.8
British Aerospace	235	+6.3

The above seven companies had space sales of over ECU 200 million in 1992, with a wide distribution between ECU 235 million and ECU 945 million. Included in this category are Europe's five big space prime contractors, one payload specialist company (Alcatel Espace), and one propulsion specialist company (SEP).

Strong growth was experienced by this group of companies, with the exception of Alcatel Espace and British Aerospace who had a growth rate of less than 10%. The space division of Alenia group and Alenia Spazio experienced the strongest growth because of the simultaneous completion of programmes and order for new programmes in which the company will significantly participate.

In the second category, six companies had space sales ranging between ECU 50 million and ECU 100 million in 1992, including one specialising in telecommunications payloads (ANT) and three specialising in launchers (Fiat/Gilardini, MAN, and Air Liquide). Fiat/Gilardini is leading this category with a little more than 100 million and the company is experiencing an upward trend in sales with the Ariane programme. Dassault Aviation's involvement in space is almost entirely related to Hermes R&D. For the first time, CASA has been included in this category in 1992 because of the impact of the Hispasat programme on its sales.

Companies	1992 Space Sales	Growth over 1991
	ECU million	%
FIAT/Gilardini	109	+20.7
Dassault Aviation	80.3	+92.5
MAN Technologie	68.6	-19
Air Liquide	65.7	na
ANT Nachrichtentechnik	62	+68.8
CASA	52.4	+7.6

The strong rate of growth for ANT Nachrichtentechnik and Dassault Aviation must be viewed in relation to their having registered a sharp decline in sales the previous year. Space sales of MAN Technologie experienced the reverse situation.

The third category consists of eight companies with space sales ranging between ECU 20 million and 50 million. These companies work on a variety of different equipment and subsystems and their growth rates are highly contrasted.

Companies	1992 Space Sales	Growth over 1991
	ECU million	%
Laben	48.4	+21
ETCA	46.8	+23.5
Fokker Space & Systems	44	+2.5
Saab Ericsson Space	38.4	na
Sextant Avionique	30.6	+2
FIAR	30.5	+36.2
Volvo Flygmotor	29.6	+1.3
SNPE	29.2	na

Based on the 1993 edition of 'Restructuring and Changes in the European Space Industry' prepared by Euroconsult, Paris.

ASTRA Satellites and European Television

Launched by Arianespace flight 56, Astra 1C entered into a geostationary transfer orbit, 199.7 km at perigee and 36,162 km at apogee. Technical staff of SES (Societe Europeenne des Satellites) started on 13 May to manoeuvre (from Betzdorf control facilities) this third Luxembourg satellite by firing its LAM (Liquid Apogee Motor). Up to six firings are required to achieve a drift orbit at an altitude of approximately 35,800 km. The new spacecraft using the HS-601 platform joins the Astra "hot bird" fleet at the geostationary position of 19.2° East.

The next three satellites will offer full redundancy with back-up capacity for the first two broadcasting satellites made by GE/RCA Astro Space.

The fourth and fifth Astra satellites will be back-ups for the frequencies used by Astra 1B and 1C. The Astra 1F satellite will be needed as a back-up for Astra 1D and 1E. Simulation tests have shown that it is possible to operate a geosynchronous constellation of up to six satellites efficiently and without risk. Astra 1D and 1E will introduce digital TV broadcasts using compression techniques.

Astra 1E will be used mainly to start TV broadcasts in digital mode and utilising the signal compression process. Pierre Meyrat, Director General of SES, stated that the future of Astra 1F would depend on the development of digital TV channels with signal compression techniques at the DBS frequencies. Depending on the digital compression ratio adopted, the number of programmes per channel may vary between 6 and 10 or even higher.

The next months will be crucial for the digital (r)evolution for TV broadcasts in Europe. Throughout 1993, the MPEG (Motion Picture Experts Group) working groups are meeting to finalize the parameters for the audio, video and multiplexing of digitally compressed signals. By the end of the year, it is intended that a uniform standard will be available for manufacturers and programmers. At this point, we should also bury the myth that it is going to take 10 years until digital TV arrives. This might be true for the production of advanced High Definition TV sets at affordable prices, but for standard digital TV transmission, even including the format 16:9, the next 24 months will be crucial. If the MPEG timetable is met, Europe can expect satellite delivered digital compression tests to commence in early 1995.

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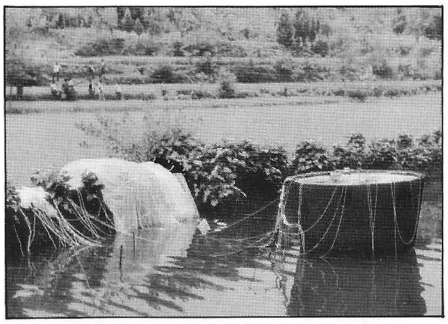
Comparisons between the Five Satellites of the Astra System.

NAME (Manufacturer)	Launch mass (lifetime)	Launch date (transponders)	Type of frequencies (bandwidth)
ASTRA 1A (RCA Astro)	1,767 kg (13 years)	11 December 1988 (16 x 47 W)	FSS: 11.2-11.45 GHz (26 MHz)
ASTRA 1B (GE Astro)	2,617 kg (14.6 years)	2 March 1991 (16 x 63 W)	FSS: 11.45-11.7 GHz (26 MHz)
ASTRA 1C (Hughes)	2,790 kg (18 years)	12 May 1993 (18 x 65 W)	FSS: 10.9-11.2 GHz (26 MHz)
ASTRA 1D (Hughes)	2,760 kg (12.7 years)	August 1994 (18 x 65 W)	FSS: 10.7-10.95 GHz/ BSS: 11.7-12.07 GHz (26 MHz/33 MHz)
ASTRA 1E (Hughes)	3,000 kg (14 years)	February 1995 (18 x 85 W)	FSS: 10.7-10.95 GHz/ BSS: 11.7-12.07 GHz (26 MHz/33 MHz)



A recovered platform. CAST

Space Microgravity in

Only by spacecraft can long-term microgravity be realised and provide the ideal conditions required for processing and producing special materials and fabricating specific drugs. In space there is no distinction between a heavy body and a light body, there is no sedimentation nor floatation, and no stratification nor convection in a liquid mixture composed of different density components. It is therefore possible to obtain alloys and composite materials of uniformly distributed components and of highly fine and close texture.

BY ZHU YILIN
Secretary General of the Science and Technology Commission of the Chinese Academy of Space Technology

Introduction

In microgravity, it is possible to fill a liquid metal of low viscosity with gas to form foam metal which is a kind of special material, light as wood and strong as steel. It is possible to manufacture bearing-balls of theoretical sphericity and to make a metal wire so thin that it can be seen clearly only with a magnifying glass and a thin metal film that is transparent.

Electrophoresis is used for the analysis and purification of certain enzymes. The operation consists of separating organic molecules and particles in a fluid-suspension. On Earth convection disturbs the electrical field and the fluid flow, but in microgravity, thanks to the absence of convection, it is possible to fabricate drugs, using electrophoresis at 400 to 500 times greater productivity and with purity several times higher than on Earth.

At present the processing of new materials and the fabrication of new drugs in space is only in an experimental phase and no large-scale economic benefit has been obtained. In the next decade, great economic benefits, as well as technical ones, are expected to be brought about.

Chinese Returnable Experimental Platforms

Since the late 1980s China has carried out materials processing and life science experiments in space microgravity on Chinese returnable satellites. Fourteen returnable satellites have been successfully launched and recovered since 1975.

The Chinese returnable satellite is an effective platform suitable for microgravity science experiments as well as a remote sensing spacecraft for Earth observation. It consists of an instrument module and a returnable module. After completing its preset tasks, the returnable module separates from the instrument module, deorbits by propulsion of its retrorockets, reenters the atmosphere, decelerates by atmosphere drag and finally lands safely on the Earth.

Two kinds of returnable microgravity experiment platforms, FSW-1 and FSW-2, have been used, and their performances are shown in Table 1.

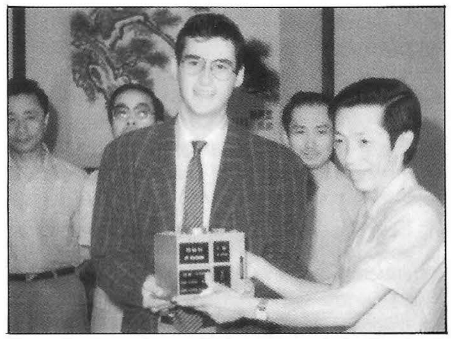
China has carried out microgravity science experiments as piggyback experiments on returnable satellites in conjunction with main payloads of remote sensors on six occasions since the first microgravity experiment was conducted piggyback on the ninth returnable satellite.

The six microgravity science experiments include 275 items for domestic and foreign users and are listed in Table 2.

Efforts in Space Materials Processing

Gallium arsenide (AsGa) semiconductors are in general use for producing super-fast integrated circuits and opto-electronics devices. Currently AsGa monocrystals grown on Earth have various defects, such as microflaws, non-uniform impurity distribution and growth fringes due to convection caused by gravity. AsGa semiconductors therefore become the focal material for space processing whenever microgravity experiments are carried piggyback on a Chinese returnable satellite.

In August 1987, China's first space microgravity experiment included two pieces of AsGa monocrystal mingled with tellurium growing with the aid of the Bridgman cooling-condensation method. The monocrystals obtained were of 1 cm in diameter and length respectively and showed no impurity fringes, indicating that their interface flaw was reduced, textural integrity improved and density of micro-sediments was lower by an order than for those grown on Earth.



A payload package that was carried piggyback on the ninth returnable satellite in 1987 for Matra, France. CAST

In August 1988, two pieces of AsGa monocrystal mingled with silicon of 1 cm in diameter and length grew onboard the eleventh returnable satellite. The monocrystals obtained showed that the segregation factor of silicon in AsGa monocrystal in microgravity conditions was four times that for those grown on Earth.

A sort of field-effect tube has been made of space-grown AsGa mono-crystal. Compared with that made of Earth-grown AsGa, its noise factor reduced 80% and correlative gain increased 23%. A continuously adjustable coherent laser of 20 mW was made up on the basis of spacegrown AsGa.

China has also undertaken microgravity experiments on the remelting and recrystallisation of mercury cadmium telluride (TeCdHg) and growth of an indium antimonide (SbIn) monocrystal mingled with zinc. The SbIn monocrystal showed no impurity fringe, the homogeneity of its resistivity and the texture integrity increasing greatly compared with an Earth-grown one.

China has also carried out coagulation tests on a series of alloys. For example, an experiment on the division of a Cd-In sample, which had been mixed together on Earth and had infiltrated the quartz tube containing it, into a Cd ball and an In ball was successfully complete, and the two balls did not infiltrate the quartz tube.

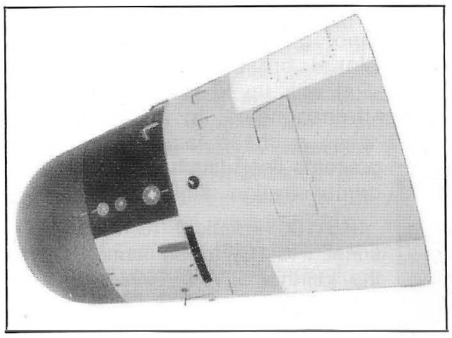
A number of monotectic alloys that are difficult to mix, such as Al-Li, Li-Nb, Al-Pb, Zn-Pb, Bi-Ga, etc., were fabricated. Most of these formed homogeneously mixed dispersion alloys.

A thermal treatment experiment of the high-temperature superconductor Y-Ba-Cu was carried out on the 1989 Chinese

Table 1: Performance parameters of microgravity experimental platforms.

Main parameter	FSW-1	FSW-2
Total mass (kg)	2100	2500-3100
Payload		
Returnable (kg)	150	300
Non-returnable (kg)	150	400-500
In-orbit time (d)	8	12-16
Perigee height (km)	200-210	175-200
Apogee height (km)	300-400	300-400
Orbital period (min)	90	90
Orbital inclination (deg)	57-70	57-70
Microgravity level (g)	10^{-3}-10^{-5}	10^{-3}-10^{-5}

Scientific Experiments China



The returnable microgravity experiment platform, FSW-1. *CAST*

returnable satellite and was the first one of such experiments in the world. The results showed that the samples treated in space had obvious differences in shape, form and chemical proportion in comparison with terrestrial samples. The distribution of crystal grains was more homogeneous and the initial transform temperature of superconductivity increased.

In addition, China has also carried out space growth research on the lithium iodite crystal for the first time in the world.

Efforts in Space Life Science

In the field of plant space experiments, a great variety of seeds were taken onboard returnable satellite, which included seeds of cereals, such as rice, wheat, soya bean, etc., those of vegetables and melons, such as cucumber, tomato, green pepper, etc., those of ornamental plants, such as cockscomb, nightshade, opium poppy, etc., and those of trees, such as chinese pine, asparagus, etc.

When recovered, the space-orbited seeds were grown on Earth and showed remarkable variations compared with terrestrial samples.

The recovered rice seeds reproduced, by cross-fertilisation, a filial generation which were of high yield rate and plump-eared grains in comparison with those of terrestrial samples. The grains of the filial generation from certain space-orbited rice seeds had 20% to 53% more protein and amino acid content than terrestrial samples respectively.

The output of the space-orbited seeds of green pepper and tomato increased 10% to 20% compared with that of terrestrial samples. In a certain group each tomato weighed 200g to 300g with the biggest one weighing 350g.

The space-orbited cucumber seeds grew rapidly on Earth, and had more female flowers and higher yields than the terrestrial samples.

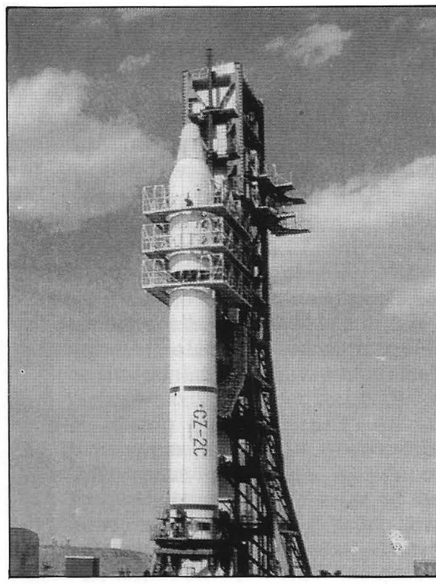
After orbiting in space the seeds of asparagus grew on Earth and germinated at a high rate and with thick stems.

In the field of space microorganism research, as many as seventeen kinds of bacteria, including fungus, flavobacterium, gibberellic bacterium, yeast etc., were carried piggyback on returnable satellites to orbit in space. The results showed that most of the bacteria survived

The plant on the left was grown from seed that had orbited for 5 days and its growth is compared with that shown by ground-based seeds. *CAST*

after 5 to 8 days in space and some space-orbited bacterium strains grew rapidly and yielded well when cultured on Earth.

Saccharification and enzymolysis activities of some space-orbited bacteria were increased. The feed fermented with these bacteria was of high productivity and a favourite for livestock to eat. When the space-orbited yeast was cultivated



The CZ-2C (Long March 2C) launch vehicle with an FSW-1 payload. *CAST*

on Earth, its enzymolysis activity increased 29% and the fermentation duration reduced to 8 to 10 days, so it will have a great application value in the beer industry.

Algae have the general characteristics of rapid growth and propagation, utilisation of light energy being 7 to 9 times greater than that of the higher plants, and the richness of their bio-chemical products place an emphasis on their use for space life research. To date China has twice carried out space microgravity experiments on algae (covering 15 different types) and obtained some varieties of algae strain whose metabolites or active substances are of medical importance.

China has also provided services of microgravity experiments to foreign users. In 1987 French Matra's algae experimental unit was carried piggyback on the ninth returnable satellite. In August 1988, Federal Republic of Germany users flew experimental units on the eleventh returnable satellite for protein crystal growth, including 101 sample tubes. Results have shown that protein crystals grown in space are of high integrity and stability.

In the field of animal space research, China successfully completed a flight test of guinea pigs in October 1991 in order to understand the effects of space flight on higher animals, making China the third country in the world to conduct animal flights.

Conclusion

China has carried out hundreds of experiments on materials processing and life science and obtained a great deal of valuable data.

Both the FSW-1 and FSW-2 returnable experimental platforms are effective and inexpensive tools for space microgravity science experiments. Using these two platforms, China will be continuing to carry out microgravity experiments and is always willing to provide piggyback experimental services with the two platforms for foreign as well as domestic users at a preferential price.

Table 2: Launch details of microgravity experimental payloads.

Order No of Satellite	Launch date	Return date	Experimental items
9	5/8/1987	10/8/1987	Growth of AsGa, TeCdHg monocrystals, plant seeds and protein crystals, etc.
10	9/9/1987	17/9/1987	AsGa monocrystal growth, Matra's experiments of microgravity measurement and algae growth, etc.
11	5/8/1988	13/8/1988	Three Federal Republic of Germany users' five experimental units weighing 30 kg.
12	5/10/1990	13/10/1990	A biological experiment capsule for guinea pigs.
13	9/8/1992	25/8/1992	TeCdHg semiconductor and protein crystal growth.
14	6/10/1992	13/10/1992	Growth of AsGa, TeCdHg, seeds of rice, wheat and asparagus, and algae.

India to Launch up to 15 Application Satellites before Year 2000

India is pushing ahead with its ambitious plans for the development and use of space technology for practical purposes.

With a yearly budget growing from $141 million for 1992-93 (1 April 1992-31 March 1993) to $219 million for 1993-94, the Department of Space, Government of India, is increasing its efforts to develop and launch satellites for Earth observations, communications and broadcasting during this decade. This budgetary growth of 55 % makes India the most dynamic country in space activities. This can be seen by the remarkable success of the highly sophisticated Insat-2A with a payload for meteorological data, for communications and broadcasting, and for data collection, search and rescue operations. Insat-2B was launched on 22 July.

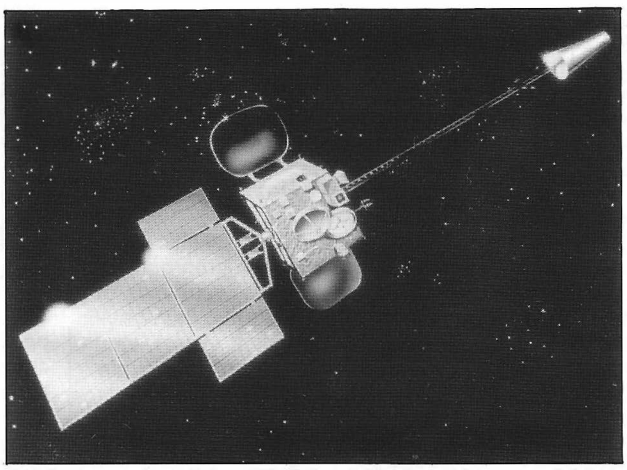
A table published in the Annual Report of the Department of Space, Government of India, shows that ISRO (India Space Research Organisation) is preparing up to 15 spacecraft to be launched in the next seven years and a half of them are to be launched from the Sriharikota Range, near Madras (Eastern coast of India). A high level of space activity is concentrated at Bangalore and in the Indian aerospace and electronics industries.

Spacecraft in preparation are:

IRS-1E, a remote sensing satellite with Indian LISS-II (Linear Imaging Self Scanners) and the German MEOSS (Monocular Electro Optical Stereo Scanner), to be launched by the first PSLV (Polar Satellite Launch Vehicle) between 10 and 15 September 1993;

SROSS (Stretched Rohini Satellite Series), with astrophysics payload, for launch by the ASLV (Augmented Satellite Launch Vehicle) during 1994;

IRS-1C, a second generation remote sensing satellite, with an improved payload consisting of cameras able to take high-resolution pictures (10-m resolution in the panchromatic mode, 20-m resolution in the multispectral mode), for launch by a Russian Vostok in mid-1994;



Artist's impression of the INSAT-2 satellite in orbit. *RACAL*

IRS-P2, with a payload consisting of LISS-II sensors and an X-ray astronomy instrument, to be launched by the second PSLV in 1994-95.

Insat-2C, augmenting the previous Insat-2 payload with a 3-channel Ku-band capacity for communications and broadcasting as well as a water vapour channel for weather pictures, to be launched by an unspecified vehicle in 1995; Ariane 4 and Proton are serious contenders for launch services.

IRS-P3, an experimental remote sensing satellite with microwave equipment - to prepare for the IRS-2 series - planned for launch in 1995-96 with the third PSLV;

Insat-2D, identical to Insat-2C, for a launch to take place with the first GSLV (Geosynchronous Satellite Launch Vehicle) in 1996;

Technological Gramsat-1 carrying educational broadcasts for the rural population with up to eight C-band high-power transponders, to be launched in 1996 when a cheap launch opportunity presents itself (such as an Ariane 5 demonstration flight);

IRS-1D, identical to the operational IRS-1C, to be launched with the fourth PSLV in 1996-97;

Insat-2E, identical to Insat-2C and Insat 2D, for a launch in 1997 with the second GSLV;

Gramsat-2, as a back-up for Gramsat-1, for a launch in 1997;

DBS-1, to improve the satellite broadcasting capacity of India over Asia, to be launched by the third GSLV in 1998;

IRS-2A, with high-resolution sensors in optical and microwave modes, for PSLV launch in 1999;

Insat-3A, with C-band and Ku-band communications payload and with improved radiometer for weather observations, for GSLV launch in the year 2000;

DBS-2 prepared for GSLV launch in the year 2000.

In the next five years, India will become fully autonomous in the development and launching of sophisticated spacecraft for communications, direct broadcasts, weather forecasts and remote sensing operations. ISRO and the Indian industry will be offering low-cost services in space technology and applications to developing countries throughout the world.

Theo Pirard

China to Launch up to 20 Spacecraft before Year 2000: Three new Long March Vehicles

China is to accelerate satellite development, the goal being to launch another 20 indigenous spacecraft by the year 2000:

1) 1991-1995: development and launch of retrievable spacecraft, meteorological satellites, large capacity comsats, broadcasting satellites new types of retrievable spacecraft.
2) 1996-2000: research and development of new types of communications and broadcasting satellites, spacecraft for navigation and positioning, for disaster detection and assistance.

China is also studying the feasibility of manned spacecraft for orbital flight and retrieval operations.

New Launch Vehicles for the Long March (LM) Family

LM-1D will be tested during 1993 from the Jiuquan Satellite Launch Center (JSLC) in Gansu Province. This three-stage launch vehicle is "derived from the LM-1 whose production has been stopped for a long time". Its improvements include: "using three-axis stabilization in the third stage instead of the uncontrolled spin-stabilized system, using two bidirectional gimballing liquid engines in the second stage instead of jet vanes; using a three-axis stabilization platform and computer instead of a strapdown guidance system; using digital values in the control system instead of analogue values and using a solid apogee kick motor in its third stage". LM-1D is designed to offer higher reliability and lower cost for the launch of small spacecraft, including mini-satellites.

LM-3A is planned to become operational in the first half of 1994 from the Xichang Satellite Launch Center (XSLC). It is a three-stage liquid launch vehicle with the first two stages stretched from the LM-2C version, but "using a newly developed third stage with two clustered LOX/LH_2 engines developing 156 kN in vacuum; two kinds of payload fairings have been designed to enable one or two spacecraft to be launched at one time". "In order to improve the guidance accuracy and adaptability, the LM-3A first stage uses a four-gimbal stabilization platform." LM-3A's capacity in GTO will be 2.5 tons.

LM-2E/HO is the LM-3A version with four liquid strap-on boosters on the first stage, following the concept of the currently used LM-2E vehicle. It will be able to place more than 4.8 tons into GTO. First flight of the LM-2E/HO vehicle, also designated LM-3B, is expected to take place in late 1994 from Xichang.

The China Academy of Launch Vehicle Technology (CALT), located in the south-suburb of Beijing and employing some 27,000 people of which about 9,000 are engineers and technicians, is engaged in the development of the Long March vehicles. It is developing a solid propellant upper stage to mate with the LM-2E. Called EPKM, it will be available for commercial flight in 1993, according to Aerospace China. The GTO capacity of LM-2E/EPKM is 3,370 kg. ***Theo Pirard***

Meteosat Programme

A Success Story with a Long Tradition

Meteosat-1, Europe's first meteorological satellite, was launched in 1977 as a pre-operational satellite. It provided a permanent view of most of Europe, all of Africa, parts of Asia, North and South America; in total over 100 countries. Meteosat-2 was launched in 1981 and Meteosat-3 in 1988.

The success of these pre-operational satellites paved the way for the operational Meteosat programme which covers the construction of three more satellites, support ground facilities and the operation of these facilities until the end of 1995.

A dedicated European organisation, Eumatsat, was set up in 1986 by 16 European states to ensure the financing and overall-responsibility for this programme. ESA oversees the construction and orbital operation of Meteosat-4, 5 and 6 on behalf of Eumetsat.

The first operational satellite, Meteosat-4, was launched on 6 March 1989; Meteosat-5 on 2 March 1991, to be followed by Meteosat-6 in November 1993.

Primetime Weather

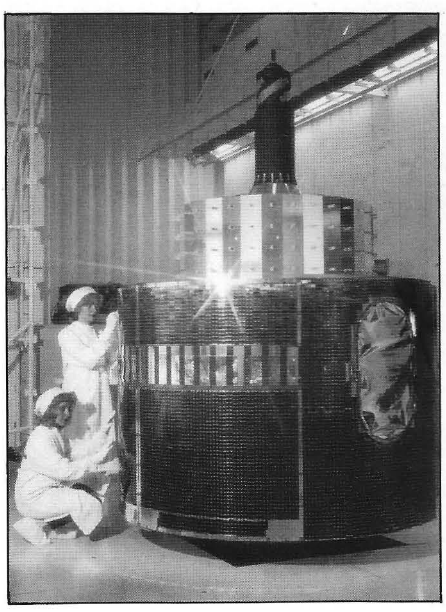
Meteosat weather images have been a feature of primetime European television for over 15 years. They have provided fast, reliable data about storms, rain, ice, drought, sun and snow. Meteorologists combine satellite data with ground measurements to make weather predictions based on complex computer models.

Two Meteosats, operating in a geostationary orbit 36,000 kilometres above the equator, provide a daily stream of weather data to users all over Europe, Africa and the United States. A third Meteosat is operated in a stand-by mode as an in-orbit spare.

Meteosat-3 Stationed over America

In January of this year Meteosat-3 moved to a new station at longitude 75 degrees West, over the South American state of Colombia. From there it will provide meteorological coverage of virtually the whole of the American continent and, most importantly, the United States of America.

The first operational Meteosat during integration at Aerospatiale's Cannes Center in 1988. *Aerospatiale*



Meteosat-3 is to become such an integral part of NOAA's forecasting service that for the first time ever, Europe has now constructed a satellite ground station in US territory, at Wallops Island, Virginia, which was inaugurated on 25 February 1993. The station was built by the Satellite and Applications Systems Division of Deutsche Aerospace (DASA/Munich).

In 1991, following an agreement between ESA and Eumetsat, Meteosat-3 was made available to the US meteorological service NOAA, to provide cover caused by delays in the US agency's new second-generation satellite service. Meteosat-3 became an instant television star as it plotted the course of hurricane "Andrew", which hit Florida in August 1992.

Between 1985 and 1988, assistance was provided in the reverse direction when NOAA made capacity available on its GOES-4 satellite to Europe to collect meteorological data.

Getting Meteosat-3 Data to the Users

An on-board communications system transmits the raw images from the satellite to the Wallops ground station in Virginia in the United States; these data are relayed by a telecommunications satellite to the Meteosat ground facilities in ESA's European Space Operations Centre (ESOC), Darmstadt, from here the spacecraft and its payload are controlled. Images are processed and meteorological products derived and distributed to national meteorological services and nearly 2000 end users. The meteorological products and image data for the United States are relayed to the Wallops station by a telecommunications satellite for distribution via Meteosat's communications payload and ground telecommunications links.

A unique feature of this system is that Meteosat-3 and the Wallops station are completely remote-controlled from ESOC in Darmstadt, including any station reconfigurations and software-updating. Trans-Atlantic telephone trunk lines and ESA-installed back-up facilities ensure redundancy of the whole communications system.

Meteosat Second Generation System

The UK software consultancy firm IPL, based at Bath, has a 12-month contract to provide high level software Quality Assurance support to Eumetsat.

The initial satellite system of Eumetsat was established by the Meteosat Operational Programme (MOP). A Meteosat Second Generation (MSG) system is under development, with the launch of the first satellite scheduled in 2000. A Meteosat Transition Programme (MTP) will provide continuity of service to the meteorological user community between the end of the MOP and the start of the MSG.

The first image obtained from Meteosat-2 on 28 July 1981 after being received and processed at ESOC. *ESA*

As part of the MTP, Eumetsat is developing a new ground system which will operate and control the Meteosat satellites after 1995. IPL will provide software Quality Assurance support in the development of the Core Facility and the Meteorological Products Extraction Facitlity (MPEF) of the new Mission Control Centre.

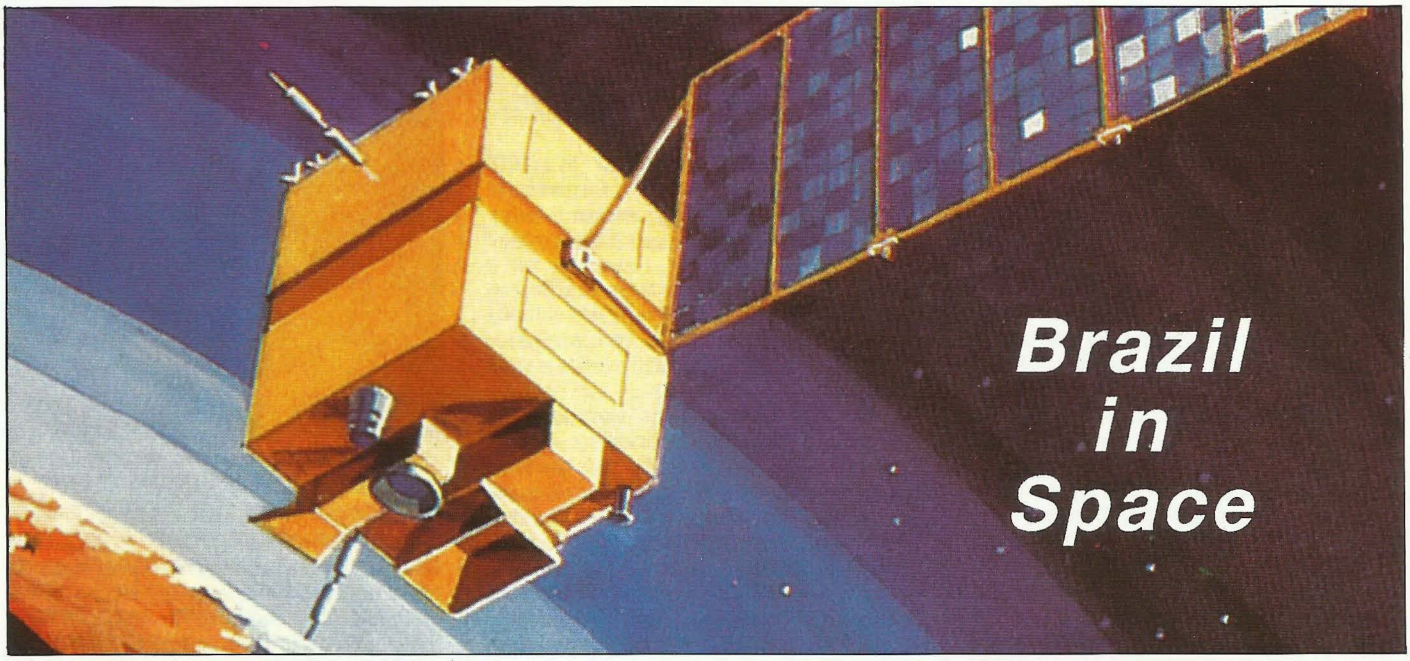
Data Distribution to be Encrypted in 1995 by Eumetsat

Because of the largely uncontrolled commercial use of the Meteosat data, especially for TV broadcasts, Eumetsat is preparing encryption/decryption techniques for their distribution. The purpose of Eumetsat is to get revenues from Meteosat operations in order to find money for the next series of second-generation Meteosat and Sun-synchronous Metop spacecraft.

Scientific and educational institutions, as well as public weather forecasting offices, will not be obliged to pay a regular subscription fee for the reception of the data. For free reception, they have to be approved by national service providers, which are members of the Eumetsat organization. Sixteen States are members of Eumetsat.

Encryption/decryption techniques are designed and prepared by VCS Engineering located at Bochum, which develops and installs professional stations for the reception and use of Meteosat and NOAA data. VCS Engineering stations are based on VAX series microcomputers and are installed in meteorological institutes not only in European countries but also, through Africa, in Kenya, Nigeria, Lesotho, Mozambique, Swaziland and Malawi.

Theo Pirard



China-Brazil Earth Resources Satellite - CBERS. *Idelfonso de Oliveira Filho/INPE*

Brazil in Space

Brazil's National Space Research Institute (INPE) was born out of the desire of a number of Brazilians to see their country participating in the conquest of space. On 3 August 1961, President Janio Quadros signed a decree, creating the Organising Group for the National Space Commission (GOCNAE) as a part of the National Research Council (CNPq). CNAE, as the institution became known later gave birth to INPE. The present activities of INPE - concentrated in the areas of Space and Atmospheric Sciences, Earth Observation, and Space Technology - and showing that space science and technology can exert an important influence on the quality of life of the general population, and on Brazil's future national development.

BY FABIOLA DE OLIVEIRA
INPE, Brazil

Introduction

Initially, the research programme at CNAE's laboratories in Sao Jose dos Campos (SP), which today is NPE's main campus, was in the field of basic research in space and atmospheric sciences and included ionospheric sounding via ground-based ionosondes and upper atmosphere research via rocket-borne payloads, launched from the Barreira de Inferno rocket range at Natal (RN).

In 1971, CNAE was replaced by the National Space Research Institute, which at the present time comes under the direction of the Ministry of Science and Technology of the Presidency of the Republic. Little by little, the use of communications, meteorological and Earth observation satellites emerged as activities close to the real needs of the country and a number of research projects were initiated: MESA - for the reception and interpretation of meteorological satellite images; SERE - using satellite and airborne remote sensing techniques for natural resources surveying; and SACI - the application of geostationary communications satellites to educational TV. Until the mid-seventies, these were the main projects being carried out by INPE.

At the end of the seventies INPE entered a new phase when the Federal Government approved the Brazilian Complete Space Mission (MECB). As a result of this INPE expanded its role to include the development of space technology. The experience gained, through the use of satellites launched by other countries, showed the development of a domestic capacity in the area of space technology to be essential to a country such as Brazil with continental dimensions and huge regions almost unexplored and largely uninhabited.

During the eighties, INPE initiated projects which today constitute priority programmes, such as MECB, the Chinese-Brazilian Earth Resources Satellite (CBERS), the Amazon Programme and the Weather Prediction and Climate Studies Center (CPTEC).

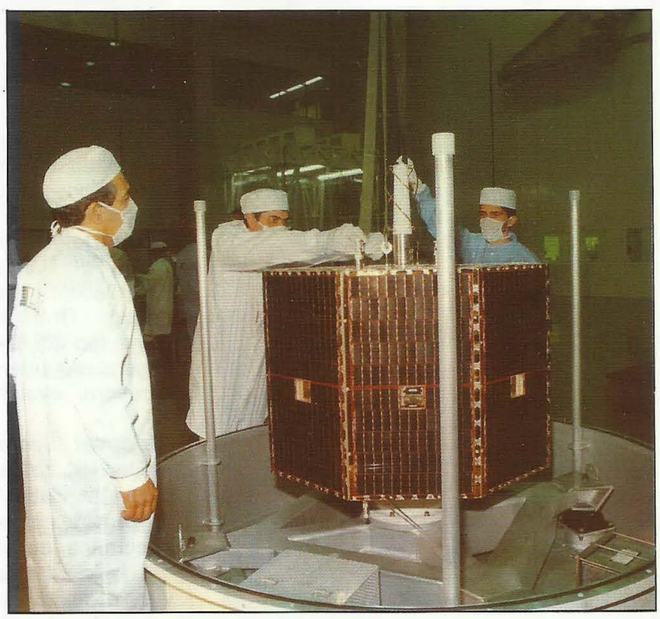
Space Technology

At the present time INPE's involvement in the construction of new satellites and space systems is mainly concentrated in two programmes: the Brazilian Complete Space Mission (MECB) and the China-Brazil Earth Resources Satellite (CBERS).

In the MECB programme, INPE is responsible for the design and construction of four satellites, two being for environmental data collection (SCD 1 and SCD 2) and two for remote sensing of natural resources (SSR 1 and SSR 2). The purpose of SCD spacecraft is to collect and relay environmental data from up to 500 automatic Data Collecting Platforms. The construction of the launch vehicle (VLS) and the launch base at Alcantara, in the state of Maranhão, are the responsibility of the Ministry of Aeronautics.

Most of the subsystems for the SCD 1 satellite have been developed by INPE with the growing participation by local industry. For the purpose of providing the necessary facilities for satellite assembly, integration and tests, INPE has set up an integration and Tests Laboratory (LIT), which is also available for indus-

INPE's technicians at the Test and Integration Laboratory (LIT) place the SCD1 in an aluminium and steel container for protection against humidity and vibrations during transport to the USA for its launch on the third Pegasus launcher on 9 February 1993. *Celso de Faria/INPE*



trial applications.

Within the Brazil-China technological cooperation programme, CBERS is a joint project for the development of Earth observation satellites. The project involves two satellites, to be launched by the Chinese Long March vehicle. INPE is responsible for 30% of the project, and is participating in all subsystems.

Earth Observation

In 1966, INPE developed Brazil's first ground station for the reception of meteorological satellite images. At the present time INPE is working in the following meteorology-related fields: climatology; synoptic meteorology; micrometeorology; numerical modelling; physical oceanography and ocean dynamics; and environmental satellite applications.

The first remote sensing satellite of the Landsat series was launched by the USA in July 1972. In the following year INPE installed a receiving station for this satellite, with full facilities for the reception and processing of satellite images. The Institute continues to collect and distribute Landsat images, and maintains user-support centres in various Brazilian cities.

It also runs post-graduate and training programmes, attended by students from Brazil and from other Latin-American and African countries.

INPE maintains remote sensing related activities in the following areas: basic research in remote sensing and image processing; forest and vegetation studies with emphasis on monitoring the Amazonian region; agriculture; geology; environmental analysis; cartography; ground stations and instrumentation; and digital image processing systems.

In 1986 the Brazilian government approved the creation of the Center for Weather Prediction and Climate Studies (CPTEC), which is being set up at INPE's Cachoeira Paulista campus. With the installation of a supercomputer, CPTEC will have the capability to make 5-day weather predictions.

Space and Atmospheric Sciences

The research programmes being carried out in Space and Atmospheric Sciences cover the areas of Aeronomy, Astrophysics and Space Geophysics. It is this area which gave rise to space activities in Brazil. The research carried out makes use of installations and laboratories essential for the development of instrumentation and the acquisition of experimental data. To this end INPE develops and launches rocket and stratospheric balloon payloads, and operates observatories for airglow studies, geomagnetic observations, ionospheric sounding, lidar measurements, ozone and radon monitoring, and radio-astronomy. Via international agreements, studies are also carried out using data from satellites launched by other countries.

Cooperative agreements with other countries have allowed researchers from the Space and Atmospheric Sciences area to participate in international programmes, mainly in cooperation with research institutes and universities in the United States, Europe, Japan and Russia.

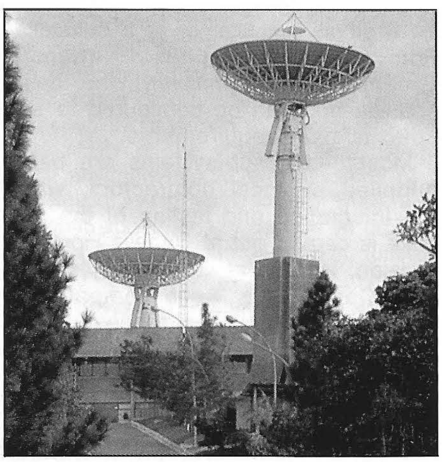
Education

Starting in 1968, INPE set up a graduate programme, aimed at providing for the country's needs for qualified personnel in space-related areas. The need for this programme was dictated by the lack of graduate schools active in the area.

At the present time, INPE runs formal graduate courses in Astronomy (Astrophysics and Radioastronomy, and Solar Physics); Space Geophysics; Meteorology; Remove Sensing; Orbital Mechanics and Control; Combustion and Propulsion; and Applied Mathematics. These courses exist at the masters and PhD levels, except for Remote Sensing and Combustion and Propulsion, which are available only at the masters level.

Apart from the regular graduate courses, INPE offers training courses in space applications such as remote sensing. These courses have been run by Brazilian, Latin-American and African specialists with the support of international organisations.

INPE maintains an Information and Documentation Service based on a library with more than 30,000 books and 1,500 journal titles. INPE's library was the first in Brazil to be computerised and is interconnected with other documentation centres in the United States and Europe.



Above: Data receiving station in Cuiabá (MT) for the second generation of remote sensing satellites. *Eduardo Girão*

Below: Partial view of the main control room of the Satellite Control Center - CCS, in São José dos Campos (SP). *Flavio Segre/Supracolor*

Brazil's Launch Plans

Brazilian space activities will significantly expand before year 2000. Oriented mainly to satellite communications and to Earth observations, up to ten spacecraft are already planned for launches from Cape Canaveral (USA), Kourou (French Guyana), Alcantara (Brazil) and Shanxi/Taiyuan (China).

SCD-1, the first "made in Brazil" satellite, was successfully launched by the third Pegasus vehicle on 9 February 1993 into a low-earth orbit with an inclination of 25° in order to give good coverage of Brazil and Amazonia.

SCD-2 will be ready for launch by late this year or early 1994. INPE (Brazil's National Institute for Space Research) is still looking for a launch opportunity, since the Brazilian VLS launch vehicle will not be ready for launch before 1995.

Brazilsat B1, using the first more powerful HS 376 W (wide) version, is developed for Embratel of Brazil by Hughes with some technological transfer to the Brazilian electronics industry. Carrying 28 C-band and 1 X-band transponder, it will be launched by Ariane 4 from Kourou in May 1994 for an operational lifetime of 8 years.

Brazilsat B2, identical to B1, will also be an Ariane 4 launch in November 1994.

SSR-1, a SCD bus equipped with a small CCD camera, will be able to transmit 200m-resolution images in two visible bands. It is developed for a possible launch during 1995 with the indigenous VLS launcher from Alcantara. It will be placed in a Sun-synchronous polar orbit at 640-km altitude.

CBERS-1 is the first remote sensing satellite developed in a joint Chinese-Brazilian venture. The optical payload of the 1.4 t spacecraft will consist of three imaging sensors: Wide-Field Imager, High-resolution CCD Camera (to produce 20-m resolution images) and Infrared Multispectral Scanner; it will also carry a Data Collection System. Launch by Chinese Long March 4A is planned during 1995-96.

SSR-2, identical to SSR-1, will be ready for a Brazilian launch in 1996-97.

CBERS-2, fully integrated in Brazil, will be ready for a Chinese launch in 1998-99.

Two 200 kg scientific satellites, within the SATCEA project, are also proposed by INPE with the purpose of carrying out some 10 ionospheric, thermospheric, magnetospheric and astrophysical experiments. They will be launched by VLS vehicles from the equatorial launch site of Alcantara. Their orbits will be circular, with an inclination of 25 degrees, at 700 km altitude. The cost for the development of the two SATCEA spacecraft is estimated to be around $15 million. INPE is looking for international cooperation to go ahead with the SATCEA project. ***Theo Pirard***

South Africa's Space Programme Takes Off

BY
JONATHAN H. SPENCER JONES
South Africa

Thorough testing of a satellite is an important part of the development process. Here Greensat is subjected to strenuous testing at the Houwteq division of Denel. *Houwteq*

The wraps have finally been lifted off South Africa's space programme with announcements by the Denel industrial group of the production of a low Earth orbit satellite system for remote sensing and the completion of an investigation into the viability of a local commercial space industry.

Coming almost exactly a year after revealing that it was involved in developing an aerospace capability and that it had launched three booster rockets from its Overberg Test Range near Bredasdorp at the southern tip of Africa, the group exhibited the satellite - named Greensat - at the 1993 Paris Air Show and are now marketing it internationally.

Greensat

Greensat is a low-cost system comprising a lightweight satellite and dedicated ground station for satellite control and image reception and processing, and provides images with a resolution of up to 2.5 metres or better with a high resolution CCD camera (at a nominal altitude of 400 km) and two-band multispectral mapping at a resolution of 16.25 metres with a second (independent) camera. About 2.3 metres tall and just over 300 kg in weight, Greensat is about half the size and only one fifth the mass of conventional Earth observation satellites and is thus substantially cheaper both to manufacture and - in particular - to launch.

According to Denel, Greensat - which will be available for launch from 1995 onwards - has been developed in response to the growing concern worldwide about the supply and management of the Earth's dwindling resources and "cost effectiveness and versatility will give the satellite a definite advantage in its niche in the market", says Mr Paul Holtzhausen, Group Executive for Corporate Communications and Environment Affairs. "It will bring resource management within the reach of virtually all resource managers, even in developing countries".

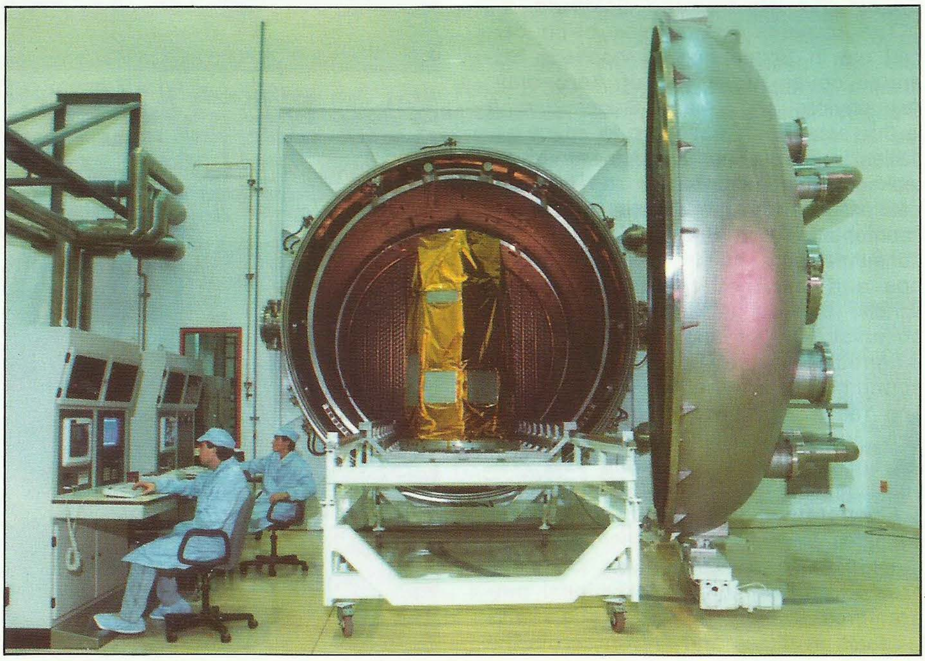
The applications of Greensat include town and regional planning, pollution control and monitoring, forestry management and cartography and it is designed to be operated either as a single satellite, or in a constellation of satellites (named Greensense). Alternatively, the basic satellite bus can be configured to suit specific user requirements.

Most of the sub-systems are being supplied by local contractors, while the integration and testing of the satellite is carried out at Denel's Houwteq division, located at Grabouw, just outside Cape Town. As a company involved in developing a resource management technique, Houwteq take considerable pride in being a recipient of one of South Africa's top environmental awards for the management of the area surrounding their facilities.

Launcher Development

Denel have also been working on the development of a satellite launcher and a series of static tests on a rocket motor have been performed at the Somchem division's Hangklip test range at Rooi Els near Cape Town.

Greensat undergoes environmental tests. *Houwteq*



This project has come under attack in the USA however, apparently over concern that such a capability - with its consequent use for military purposes - could fall into the wrong hands under a new regime in South Africa.

With the completion of the feasibility study, Denel have concluded that it would not be economical to manufacture launch vehicles and the project is to be terminated "at a logical cut-off point" after some remaining motor tests, "aimed at gathering information relating to the qualification of support systems for Greensat and other satellites" says Mr Holtzhausen.

It is not intended to close the Hangklip or Overberg test ranges however, and they will continue to be used for testing "other products". The Hangklip range is contained within an area of only 2 hectares and consists of a control centre housing measuring and test equipment and a bench for anchoring rocket motors, while the Overberg Test Range (a separate Denel division), covering a land area of 43,000 hectares, including 70 km of coastline, contains instrumentation such as tracking radars, cine theodolites, Doppler tracking receivers and a fully-equipped central Command and Control Room.

Sunsat

A second satellite programme, Sunsat, has also been underway in South Africa since mid-1991. A microsatellite being developed under the leadership of Professor Garth Milne at the University of Stellenbosch, Sunsat - an acronym for Stellenbosch University or Sunny South Africa satellite - will be a cube of size 450 mm by 450 mm by 400 mm high and weight of about 50 kg, and will carry a payload including a 20 metre resolution stereo imager and a store-and-forward message transfer device.

Sunsat is being supported by several South African companies including Altech, Grinaker Electronics, Plessey Tellumat, Siemens and AMS, as well as the SA Amateur Radio Satellite Association (SA Amsat), and despite limited financial resources, good progress is being made with twenty Masters degree students currently working on it.

One of the goals of the project is to stimulate interest in science and technology and "student sponsorship by Advisory Board companies and Grinaker's Satellite Systems Chair are evidence of their belief in the technological future for the country and the long term need for competent engineers", says Prof Milne.

At its last meeting in April 1993, the Advisory Board gave a mandate to complete the engineering model by the end of the year and re-affirmed that the development should proceed through launch, which is not likely to be until 1995. There are still "possibilities for participation in Sunsat by interested parties", comments Prof Milne.

National Space Involvement

In order to manage this growing space industry, the State has passed legislation to establish the South African Council for Space Affairs. To be appointed by the Minister of Trade and Industry, the Council will be composed of representatives with "applicable knowledge or experience" and its duties will include the regulation of space activities to comply with international treaties, and co-ordination of the space industry and liaison with other space agencies and international bodies.

South Africa has been involved in space almost since the start of the space age. One of the earliest activities was the operation of a tracking station at Hartebeesthoek, 30 km north-west of Johannesburg, on behalf of NASA from 1961 to 1974 (after which it became the Radio Astronomy Observatory) and for over 25 years, the Council for Scientific and Industrial Research has maintained the Satellite Applications Centre, also at Hartebeesthoek, for the reception and

supply of remote sensing and meteorological data. Additionally, South Africa is a signatory of Intelsat and is planning to become one of Inmarsat, while also the country's broadcasters have signed a contract with PanAmSat for rental of Ku-band transponders on the PAS-4 satellite to provide a direct-to-home satellite TV service.

The country is now going through an exciting time in its history: nationally, political change is occurring as the old order inexorably makes way for the new and internationally, it is once again taking its place as a member of the world community. The South African space industry too, is seeing exciting developments as it heads for take off.

From the 1993 Paris Air Show

Greensat

Andy Salmon visits the Houwteq stand:

Greensat is the satellite system that claims it will do for space applications what the PC did for computing applications.

Developed by Houwteq, a division of the South African industrial group Denel, it comes in a "one stop shopping" package of: satellite, ground station and image processing system. This package and its low cost makes it ideal for developing countries.

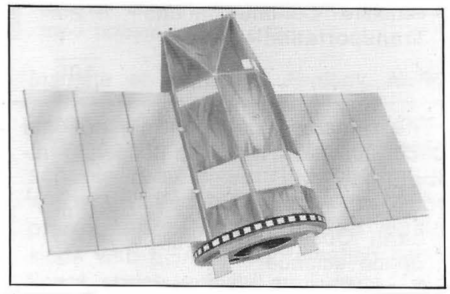
The field of application is Earth observation: remote sensing for mapping, environmental protection, surveillance and disaster management.

The satellite's total mass is 320 kg, low enough for launch by, say, OSC's Taurus small launch vehicle. Orbital height is 200-700 km and design life is 2-5 years. The payload consists of:

1. A high resolution panchromatic CCD camera
   500-900 nm spectral range
   2.5 m resolution at 400 km height (swath width: 8 km)
2. A multi-spectral mapping CCD camera
   630-690 and 760-900 nm bands
   16.25 m resolution at 400 km height (swath width: 120 km)

The high resolution images would show finer detail than any Western offering - as good as photography from aircraft - thanks to long focal length folded optics.

The cameras operate independently and the satellite can be pointed up to 45 degrees off its ground track to capture



Greensat. *Houwteq*

BY ANDY SALMON
West Midlands, UK

images. Three-axis stabilisation of the satellite is used to provide a stable imaging platform. To keep satellite mass down there is no data recorder onboard: images are transmitted in real-time to a ground station up to 2,000 km distant.

The satellite operates independently during "cruise" mode but orbit correction and imaging tasks are planned and controlled by a ground station.

The satellite appears a little like the Israeli "Ofeq" (Horizon) series. Houwteq's satellite bus is offered for tailoring to a customer's payload. More than half of the components are made by South African industries.

Solar panels provide 400 W of electrical power.

Houwteq is now looking for international partners in its venture and the first satellite could be launched in 1995.

Information courtesy of Fanie Gerber, Houwteq.

UK Space Activities

The British National Space Centre (BNSC) was formed in 1985 as a partnership between government, research councils and others. It provides Britain with a focus for non-military space activities and advises Government on space developments and opportunities, carrying out the resulting policies. Its recent publication 'UK Space Activities 1992/93' gives an overview of the country's main areas of space commitment in terms of particular projects, missions and financial support.

Where the Money Comes From

The total 1992/93 UK space budget of £170 m is made up of allocations from:

	£ m
Department of Trade and Industry	95
Science and Engineering Research Council	53
Meteorological Office	16
Ministry of Defence	5
Natural Environmental Research Council	1
	170

Where the Money Goes To

Of the total £170 m, £106 m is contributed to ESA with the following allocations:

	£ m
Earth Observation	40
General, HQ	15
Science, Microgravity	30
Satellite Communications	20
Transportation	1
	106

The remainder is spent on national space activities with the following allocations:

	£ m
Earth Observation	45
Space science	14
Technology	4
Satellite communication	1
	64

Earth Observation

These figures confirm Earth Observation as the centrepiece of British space policy with 50% of the UK space spend. UK industry is involved in the development of ESA's ERS-2 Earth Observation satellite and leads in the 'Polar Platform' to be utilised in ESA's long-term plans for a series of ENVISAT (environmental) and METOP (meteorological) missions which will extend well into the next decade.

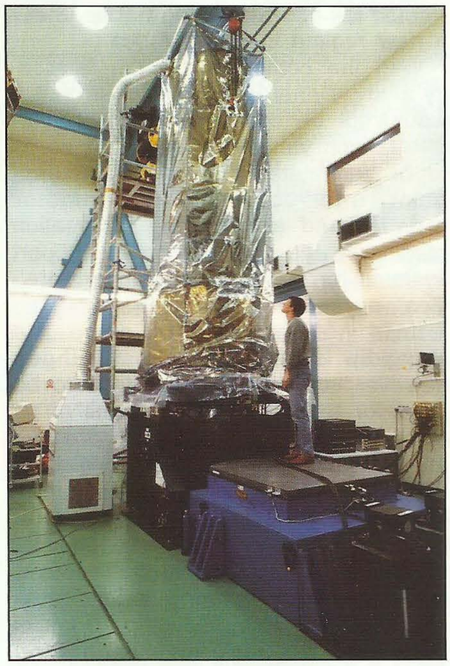
BY MIKE BLACKWELL
British National Space Centre

With ERS-1 operating successfully and future programmes taking shape, attention is now shifting to data exploitation - ensuring that the data flow from space is adequate and that the necessary techniques and technologies are in place. Britain hosts one of the four ESA 'Processing and Archiving Facilities' (PAF's) at Farnborough which is operated by the National Remote Sensing Centre Ltd.

Space Science

BNSC science funding supports UK universities and Rutherford-Appleton Laboratory (RAL) in developing new instruments for space missions and for the interpretation of data.

Highlights of the past year include the reactivation of the Giotto spacecraft after its encounter with Halley's Comet for a further cometary encounter, this time with Comet Grigg-Skjellerup; and also the award to RAL of ESA's contract to host and run the Cluster mission science operations centre.

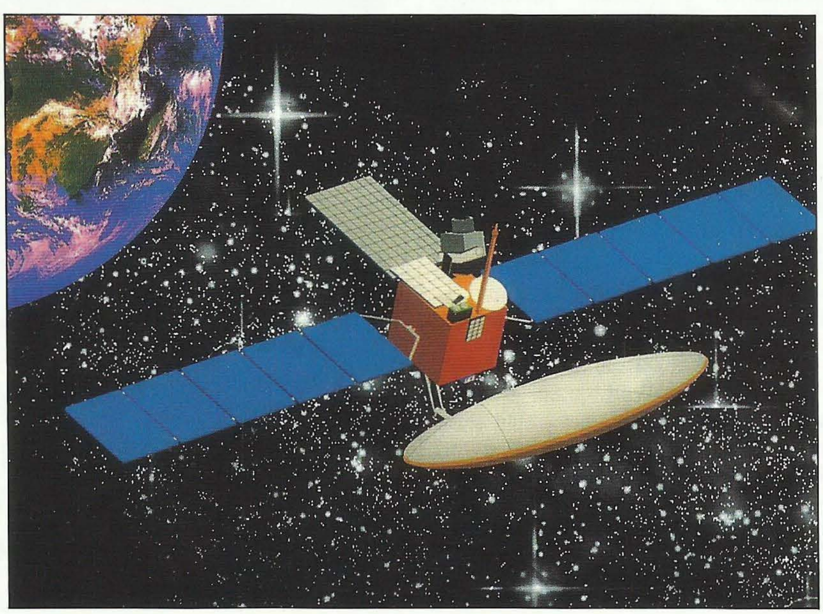


JET-X on the 160,000N shaker at Bristol Aerospace Systems Ltd., Stevenage. The 551 kg telescope was subjected to sinusoidal, random and shock vibrations in all three axes at levels from 40g shock pulses down to 0.25g resonance searches. Random vibrations of 7.5g RMS for 10 minutes in each axis simulated launch vibrations. Seventy-five accelerometers measured the response. *BAe*

Forthcoming science missions for which UK preparations have been underway are:

- **Ulysses**, a solar mission to overfly the south pole of the Sun in 1994 and the north pole in 1995.
- **ISO**, ESA's infra-red Space Observatory to be launched in 1995 to study star formation, galaxies and other objects.
- **SOHO/Cluster** (due for launch in 1995) to study Earth/Sun interaction - SOHO as an observatory at the balance point between the Sun/Earth gravitational fields and Cluster as a group of four identical spacecraft designed to give 3D data on magnetic and electric fields.
- **Cassini/Huygens**, an ESA/NASA mission due for launch in 1997 to study Saturn and its large moon Titan.
- **X-ray Multi Mirror Mission** (XMM, due for launch in 1999) will be ESA's largest satellite and will study X-ray emissions from faint sources.

Artemis will carry out trials for data relay and land mobile services. *BNSC*



1992/93

- **JET-X**, the UK-led X-ray telescope that is on course for launch in 1995 on Russia's Spectrum-X mission.

Satellite Communications

Satellite Communications provided Britain's first opportunity to put space to work and the resulting global market is one in which UK industry continues to successfully compete.

Through BNSC, Britain takes part in a number of ESA satellite communications programmes:

- **Data Relay and Technology Mission, DRTM:** This programme has two elements:

  Advanced Relay and Technology Mission, Artemis: will provide a pre-operational data relay capability and demonstrate links with land mobile terminals, optical intersatellite data linking and electric propulsion:

  Data Relay Satellite, DRS: The first of the two planned DRS satellites will support transmission to Earth of data collected by ENVISAT-1 where there are no ground stations.

- **Advanced Systems Technology Programme, ASTP-4:** will develop ESA's new satcoms technologies. Should assist UK industry's competitiveness (e.g. the development of microwave integrated circuits for ground mobile terminals).
- **Advanced Research in Telecommunications Systems (ARTES):** ESA Ministers agreed at Granada to this new programme, which brings together all future ESA satcoms programmes (including PSDE, the Payload Spacecraft Development Experiments, and ASTP-4) within a single framework.

Space Transportation

With a growing range of commercial and multinational space launchers already available, Britain decided not to take part in future launcher development. However, we remain a minor player in ESA's launcher programmes being involved in the Ariane 4 *Research and Technology Accompaniment Programme*.

UK industry benefits from orders for production items to meet the Ariane launch schedule, for example, Ferranti's inertial platforms have always been at the heart of the launcher's guidance system and British Aerospace is supplier of the SPELDA carbon-fibre structure that allows two satellites to be injected into orbit from a single Ariane 4 launch.

Ministers at Granada endorsed the concept of a programme to investigate future re-usable launchers (FESTIP, the Future European Space Transportation Investigation Programme), and BNSC is working with ESA to help develop the technical content of the programme.

Education

Within education, BNSC has worked closely with the Department for Education to further space applications, helping arrange for a teaching pack (*'Remote Sensing in the Science Curriculum'*) to be published for schools (a geography pack follows). A new BNSC reference directory, *'Space and Education'*, was published to match *'Space and Industry'*.

During the last year the 'Earthwatch' schools remote sensing competition winners visited NASA as one of their prizes, and BNSC initiated discussions with ESA on coordinating educational space activity in Europe.

BNSC has worked closely with the 'BISY' (British Industry in Space Year) and 'Eurisy' (Europe in Space Year) awareness campaigns, successfully co-hosting a major exhibition stand with BISY at the 1992 Farnborough Air Show.

BNSC's range of information materials now includes the new awareness video 'Perspectives on Space'.

Science Museum Display

BNSC and the Science Museum have come together to present a display at the Museum on *UK Space Activities*. It runs from October to December 1993 and provides an excellent opportunity to find out about Earth observation, space science and Britain's other aims and achievements.

The display is located within the Museum's Space Gallery where displays include the actual Apollo 10 capsule that orbited the Moon in May 1969 and many other items that trace the history of rocket travel from its origins to today's space shuttles and beyond.

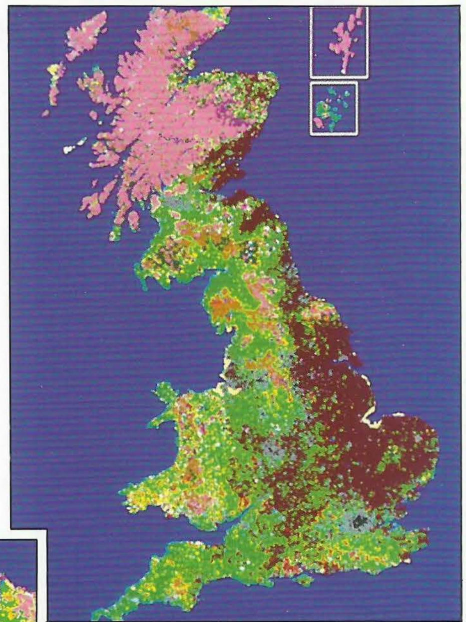
Winners from Purley VIth Form College of 'Earthwatch' - one of BNSC's many successful education activities. *BNSC*

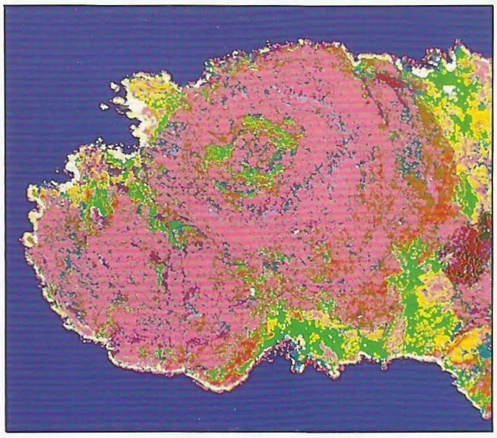
Land Cover Map of Great Britain

The Land Cover Map of Great Britain, developed by the Institute of Terrestrial Ecology (ITE) records 25 cover types, giving the dominant component for each 25 m cell of the British National Grid.

The map shows the structural detail such as waterways, urban developments, motorways, embankments and tree-belts. General patterns are shown at the field-by-field scale.

The land cover map has been produced using cloud-free images from the American Landsat satellite, between 1988 and 1991. The on-board sensor records the reflected solar radiation in seven wavebands of the spectrum from ground cells about 30 m across.





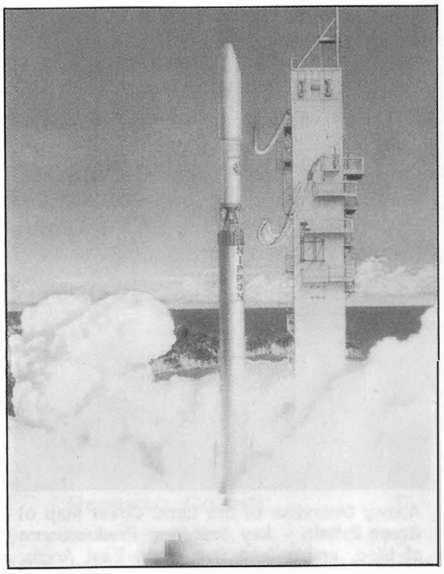
Above: **Overview of the Land Cover Map of Great Britain - key features:** Predominance of tilled, arable land (brown) in East Anglia; agricultural grasslands (green) in the West Country; grass moorland and bracken (tan and orange) in the Lake District and S Scotland; and heather/grass moors (pink) throughout much of N Scotland.

Left: **Ardnamurchan Point, W Scotland - key features:** A long-extinct volcano, showing concentric patterns of heather-grass moor (pink), bogs (turquoise), bracken (orange) and grasslands (green) around the bare rim of the crater which shows as scattered patches of light grey.

Source: Environmental Information Centre, Institute of Terrestrial Ecology, NERC.

Japan: Three New Vehicles

Spacecraft to be Launched for Exploration,



The J-I launch vehicle is a three-stage solid rocket space booster. The first stage is the solid rocket booster of the H-II vehicle. *NASDA*

NASDA (National Agency Space Development) of Japan and ISAS (Institute of Space & Astronautical Science) have ambitious plans for programmes in space transportation and applications. Between 1994 and 2000, they will be working on the preparation of three launch vehicles and of powerful high performance spacecraft. Each year, launch times in Japan, because of fishing activities, are restricted to Winter (January-February) and to Summer (July-August) periods.

February 1994: First test flight, from Tanegashima Island (Yoshinobu Launch Complex), of the new H-II launch vehicle to carry an experimental payload consisting of VEP (Vehicle Evaluation Payload) and the recoverable OREX capsule (800 kg).

August 1994: Second test flight of H-II to place into geosynchronous transfer orbit the technological ETS-VI (Engineering Test Satellite) communications satellite (2 t in GEO).

August 1994: The eighth and last M-3SII solid rocket used from Kagoshima to launch the German EXPRESS-1 spacecraft with a "made in Russia" capsule for microgravity experiments.

February 1995: SFU (Space Flyer Unit) and GMS-5 (Geostationary Meteorological Satellite) respectively to be launched in low orbit and in geostationary transfer orbit by the third H-II; the SFU will be retrieved in orbit by a NASA Space Shuttle during the Summer of 1995.

February 1995: First J-1 demonstration flight - combining solid motors of M-3SII and H-II rockets - from Tanegashima to test a reduced model of the small spaceplane, called Hyflex (as part of the development programme of the HOPE vehicle).

August 1995: First mission of the new and powerful M-V vehicle to place in elliptic orbit the MUSES-B spacecraft, a

An illustration of an AMOS communications satellite in geostationory orbit at 15°E. *ISA*

Ten years have gone by since the creation of the Israel Space Agency and Israel is now entering a period in which several major projects have graduated from the drawing board and are bearing fruit.

EDITED BY ABRAHAM TAL
Tel Aviv, Israel

The launch into low Earth orbit of OFEQ-1, the first Israeli satellite, on 19 September 1988, introduced Israel into the small group of nations who build and launch their own satellites. In the following years, much progress was made in the field of space research and space technology, with a modest budget. Thus, on 3 April 1990, OFEQ-2, an improved version of its predecessor, was launched into a similar orbit and functioned perfectly during several months in space. A second generation, three-axis stabilised satellite is currently being built.

AMOS communications satellites are being built and will be placed in a geostationary orbit in 1994. TECHSAT - a student built microsatellite - will be launched into low Earth orbit in 1994. TAUVEX, a cluster of three ultraviolet telescopes, will be launched in 1995 on board a European scientific satellite.

Hopes for a boost in Israel's industrial and commercial applications rely mostly on the "AMOS" communications satellite, but the country is also embarking on a commercial activity in remote sensing. The field of high resolution image data, starting with the US "Landsat" satellite in 1972, has been a steadily growing business, duly commercialised and privatised. In the past Israeli scientists have collaborated with NASA on research aimed at the application of these techniques to desert areas. Israel may now enter directly into this field on its own.

Israel's first scientific payload, TAUVEX, is an ultraviolet imaging system, operating at three wavelengths, centred at 1500, 2000 and 2500 A. A second-generation satellite with three-axis stabilisation and pointing capability, as required by a scientific payload, with a life expectancy of approximately two years, is planned for launch in 1995.

An interim satellite, having some of these capabilities but without the scientific payload is to be launched in 1993 to test the newly developed systems.

Propulsion Technology

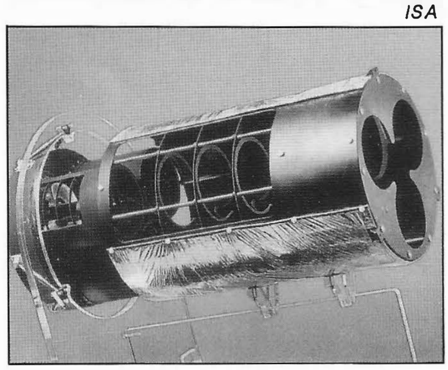
One of the projects for which the Israel Aircraft Industries (IAI) Electronics Division is responsible is the Cryogenic Transfer Module (CTM). This is a major space technology advance, now in development, which will be capable of transferring a 2.1 ton satellite from a 200 km low Earth orbit (inclination 28.5) to geosynchronous orbit.

The CTM is entirely independent of the satellite payload during the entire transfer mission. It is powered by a cryogenic propulsion unit of 10,000 N thrust, using liquid oxygen and liquid hydrogen. Total burn time is 2100 seconds, typically divided into five discrete burns, four at perigee and one at apogee. The stage mass fraction is 0.87 with a maximum cryogenic propellant mass of 4800 kg. Ground tests of the propulsion unit have commenced.

Communications Satellite System

IAI/MBT Systems and Space Technology is a major subsidiary of IAI and is developing a geostationary domestic communications satellite system DOMSAT. The space segment of the system includes one or two light weight - 950 kg dry - AMOS satellites, each with up to seven active transponders.

TAUVEX, Israel's UV astronomical satellite. *ISA*



Before the Year 2000

Technology and Applications

BY THEO PIRARD FBIS
Belgium

large interferometer for radiowave astronomical observations.

February 1996: Fourth H-II launch to carry the heavy (3.2 t) ADEOS-1 spacecraft in sun-synchronous orbit for Earth observation.

August 1996: Planet-B probe launched by M-V from Kagoshima to reach a Martian orbit for studies of the atmosphere of Mars.

February 1997: COMETS (Communications & Broadcasting Engineering Test Satellite) launched by a fifth H-II for demonstration of new advanced technologies.

August 1997: Lunar-B probe launched by M-V to orbit the Moon for studies of the crust and thermal structures.

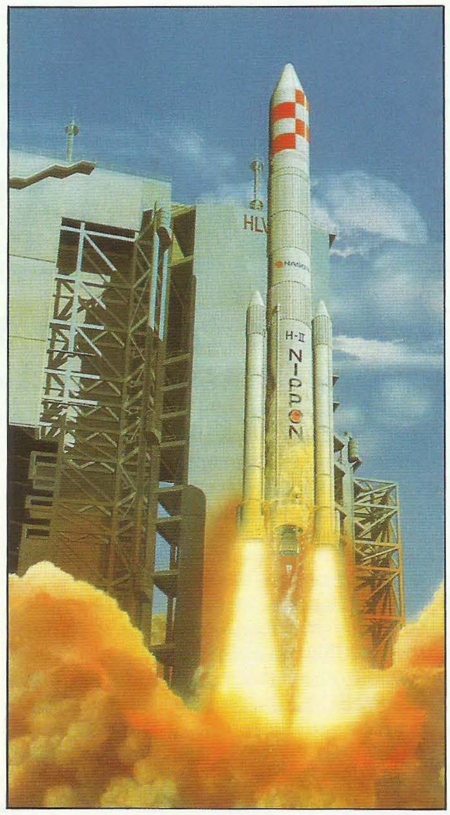
August 1997: TRMM (Tropical Rainfall Measuring Mission, a joint NASDA-NASA spacecraft of 3.5 t) and ETS-VII technological satellite (2.6 t in 550-km circular orbit) to be launched by H-II from Tanegashima.

1998: Launch and installation of the JEM (Japanese Experiment Module) developed by NASDA on the International Space Station (following present plans if these go ahead).

February 1998: Second launch of the J-1 rocket with an ETS spacecraft to test elements for in-orbit infrastructure (possibly).

February 1999: ADEOS-2 spacecraft for environmental measurements, to be launched by H-II and to continue the ADEOS-1 mission.

August 1999: COMETS-2 communications and broadcasting satellite scheduled for launch with H-II.



The H-II launch vehicle is a two-stage rocket equipped with two large solid rocket boosters. *NASDA*

The first system is planned to be placed in geostationary orbit at 15° East for Israel's domestic communications. It will consist of two satellites each having seven active transponders, operating at 72 MHz, mainly in the Ku band. The footprint of the satellites will cover Israel with a 1° and 25° beam.

The system is to be used for domestic telephone, telex, telefax and television, for national, as well as private, networks. Three or four television channels will be provided, one or two of which will be capable of Direct Broadcast Services to satellite receptors of less than 1 metre.

The first of the satellites is to be launched by Ariane-4 in late 1994.

Students' Satellite

All stages of TECHSAT from concept through design, system and subsystem construction, integration and testing of both space and ground segments, are performed by the students and staff of the Technion with strong support from industry and from the Israel Space Agency.

TECHSAT-1's launch is to be by Ariane in 1994 into low Earth Sun synchronous orbit. The satellite platform will be lightweight and low cost and is designed to carry several types of payload.

The ground station, to be set up at the Technion campus, will serve the command, tracking and communications functions after launch. TECHSAT-1 will be the first of a series of 4 satellites to be launched at several year intervals.

Israel looks to its achievements in space to contribute to the development of its economic and industrial potential and thus have an overall impact on its national progress

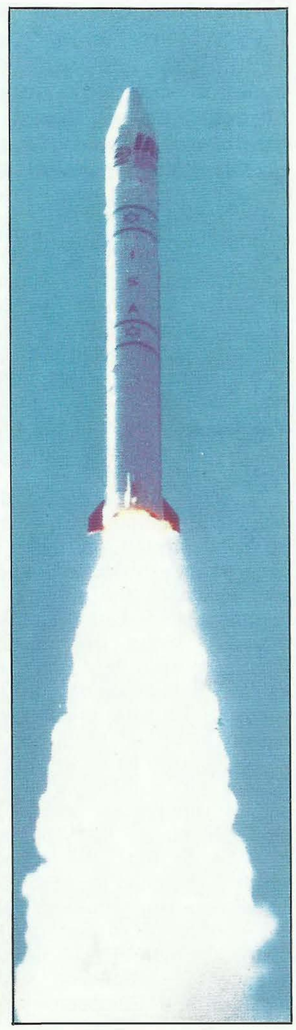
*(For more details see the **JBIS**, December 1992 which is a special issue entitled 'Israel Space Agency').*

Israel's Two Satellite Launches

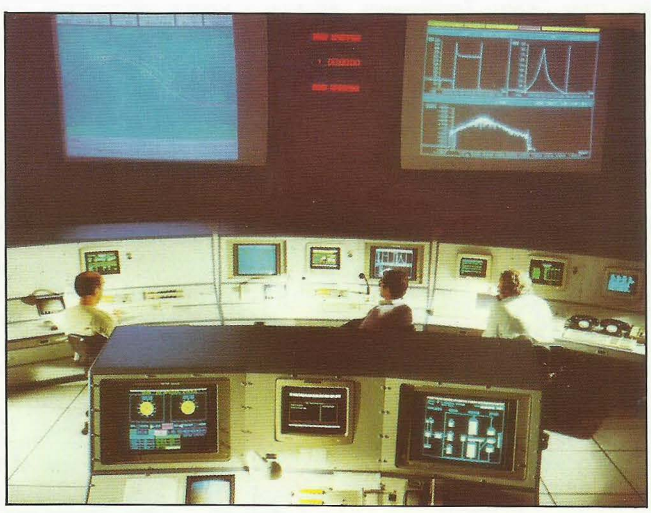
On September 19, 1988, after many years of planning, research and development, Israel launched its first satellite OFEQ-1 into orbit. The 156 kg experimental satellite was designed and built by the Israel Aircraft Industries, who were chosen to be the main contractor for the current Israeli space programme. Its main objectives were to test the capability to launch a payload into orbit and the functional ability of the structure and instrumentation in the space environment. Several functions of the ground control station, such as tracking, were also tested. It remained in space for 118 days in an orbit with an apogee of 1150 km and a perigee of 248 km, functioning even better than expected.

On April 3, 1990, a second satellite OFEQ-2 was launched into a similar orbit, with an apogee of 1580 km and a perigee of 210 km. Having the same systems as those launched on board OFEQ-1, the second satellite had better thermal and cosmic rays protection, improved gyroscopes and magnetometer, an enlarged on-board computer and a two-way communications capability. All systems operated perfectly.

Lift-off of the OFEQ-1 satellite by an Israeli launch vehicle. *ISA*



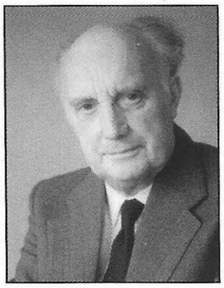
Mission Control Centre for Israeli satellite launches. *ISA*



Society News

Sixty Years Promoting Space

The Society was founded in Liverpool in October 1933 at a time when interplanetary flight was under consideration abroad, notably in the USA, Germany and Russia. About the early days, Philip Cleator, founder of the Society later wrote:



P.E. Cleator, Founder of the Society.

"...reports about the experimental activities of the 'Verein für Raumschiffahrt' (Society for Space Travel) in Germany had begun to appear in the Press. This electrifying news was followed by word of the formation of an Interplanetary Society in America, with whose Secretary I was soon in touch. Among other things, my correspondent expressed the hope that a kindred organisation was about to make its appearance in the land of my birth"

Through sixty years of space history, the Society has always been at the forefront in promoting space research, technology and applications. In its 'Diamond Jubilee Handbook', the President, Anthony T. Lawton writes:

A.T. Lawton, President of the Society

"For sixty years now, the Society has actively promoted space exploration in the widest possible sense to every section of the community, embracing not only the great advances in space technology but also the many opportunities which exist for scientific exploration and the eventual utilisation of space for the benefit of mankind". "The Society serves the interests of both those who are professionally and technically associated with this work as well as those with a general interest who wish to keep abreast of the latest developments".

During 1992-93, the Society has marked its 60th anniversary with a programme of special activities, culminating with the forthcoming event of SPACE '93 on 15-17 October. This important meeting will provide a great opportunity for all members to come together for a special Society occasion. Please see opposite for details and contact the Society as soon as possible for further information and registration.

Electric Propulsion of Spacecraft

Technical Symposium of the Society, 19 May 1993

As part of the programme devised to mark its 60th anniversary, the Society sponsored a very successful symposium devoted to advanced electric propulsion (EP) systems, which was held at the BIS HQ on 19 May 1993. The programme of the Symposium covered systems currently under development in Europe, and attracted seven expert speakers, together with a large audience drawn from industry, the universities, government agencies and the Society's membership.

After an introduction by the Chairman, Dr David Fearn of DRA, Farnborough, in which he drew attention to the advantages of EP, the first speaker, Mr Georgio Saccoccia of ESTEC, set the scene by summarising the status of this technology within Europe. He also compared European activities with those in the rest of the world, primarily the USA, Russia and Japan.

Although Mr Saccoccia dealt with all European programmes, he concentrated on those not covered by subsequent speakers, including the arcjets and magnetoplasmadynamic (MPD) thrusters being developed in Germany and Italy, and also ESA's field-emission thruster concept. The latter is capable, in pulsed mode, of producing the lowest impulse bit of any thruster system and is therefore of interest for ultra-precise attitude and orbit control. Its first application may be to the LISA mission, which is designed to detect gravity waves. He also emphasised the significance of the flight test of the German RIT-10 radiofrequency ion propulsion system (IPS) on the European Retrievable Carrier, Eureca, which is the first-ever European EP mission. As the spacecraft has now been returned to Earth via the Shuttle, there is an unprecedented opportunity to examine the condition of this thruster following its operation in space.

The next paper dealt with an equally exciting prospect, ESA's Advanced Relay and Technology Mission, ARTEMIS, which is the initial phase of the Data Relay and Technology Mission (DRTM). This programme was described by the DRTM Payload Manager, Mr Gotthard Oppenhauser of ESTEC. The ARTEMIS spacecraft carries advanced communications and platform technologies, including an IPS and a laser-based intersatellite communications link system, which requires pointing accuracies of 8 microradians, or 0.0005 deg.

For operational north-south station-keeping (NSSK), the spacecraft will rely on the IPS, which consists of two RIT-10 thrusters and two UK-10s, together with their associated power conditioning, control and propellant feed systems. This scheme provides redundancy both as regards number of units and from the point of view of technology. As well as allowing a substantial enhancement of payload mass, which is vital to the mission as planned, the IPS eliminates the disturbance to the pointing of the communications laser that would result from the use of conventional chemical thrusters for NSSK.

Dr Tony Martin of AEA Technology's Culham Laboratory then described the application of nuclear power sources to EP missions, a subject studied widely for three decades but now approaching realisation. It now appears that the first flight of such a nuclear EP mission, at least in the West, will be of a Russian TOPAZ 2 reactor powering a wide variety of EP devices; this mission, funded by SDIO, has selected as candidate thrusters devices from the USA, Russia, France and the UK. The latter is a T5 Kaufman-type ion thruster to be supplied jointly by DRA Farnborough and Culham; the T5 thruster is also part of the UK-10 system to be flown on ARTEMIS.

Mr Peter Smith of Matra Marconi Space UK then described the UK-10 IPS in some detail, explaining how it will be integrated with the ARTEMIS spacecraft. He was followed by Dr Jochen Hofmann of DASA/MBB, who covered the RIT-10 IPS, commencing with an account of its development history. He also presented some of the latest data from the Eureca flight.

The next section of the meeting dealt with the larger European ion thrusters, the UK-25 and the RIT-35. Reference was also made to a plan by ESA to combine the best features of these devices to produce the ESA-XX, the diameter of which has not yet been defined.

Mr Paul Latham of the Culham Laboratory described the UK-25 thruster, which has now demonstrated a performance well above its design specifications, a thrust of 316 mN. having been achieved. Dr Klaus Groh from the University of Giessen covered the RIT-35 in similar detail, presenting comprehensive experimental data.

Finally, Paul Latham returned to the rostrum to give a paper on the Russian stationary plasma thruster. This achieves a high exhaust velocity by means of an interaction between the discharge current into an annular chamber and a radial magnetic field. It has proved to be extremely effective in more than 50 flights, has been extensively tested in the West, and is likely to fly, at two widely different thrust levels, on the Topaz 2 test mission.

This very interesting meeting covered the world scene in electric propulsion briefly, but concentrated mainly on European activities. It showed that this technology is close to operational maturity and that Europe is competing on equal terms with the rest of the world. After many years as an interesting research topic, electric propulsion is now entering its application phase, and much is expected of it.

Dave G. Fearn

1933-1993: BIS 60th Anniversary Meeting

SPACE '93 Welcomes Lunar Astronaut Buzz Aldrin

at

White Rock Theatre, Hastings, E. Sussex

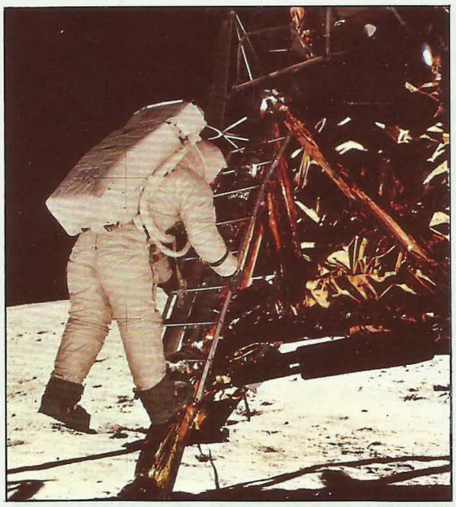
15-17 October 1993

Live Satellite Link-Up - Hastings to Sri Lanka

(Courtesy of INTELSAT, EUTELSAT and BT)

Among the special guests and visitors to this weekend meeting will be Buzz Aldrin who on 20 July 1969 became the second man to walk on the Moon.

He will participate in a question and answer sessions at the Anniversary Dinner of Saturday, 16 October and in the satellite link-up between Patrick Moore in Hastings and Arthur C. Clarke in Sri Lanka on Sunday, 17 October.



Astronaut Edwin E Aldrin Jr., Lunar Module pilot, descends the steps of the Lunar Module ladder as he prepares to walk on the Moon.
NASA

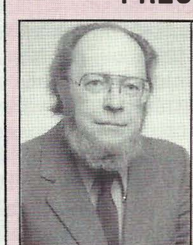
CIVIC RECEPTION
(Courtesy of Hastings Corporation)

Friday Evening, 15 October

Marina Pavilion
St. Leonards-on-Sea

Buffet together with entertainment to which all participants are invited.

PRESENTATION



The BIS Special Achievement Medal will be presented to Dr W. I. McLaughlin for outstanding contributions to the advancement of astornautics over many years.

SPACE EXHIBITION

Exhibitors include Matra Marconi, BNSC and Logica.

Commemorative BIS Tie 1933-1993

To celebrate its 60th anniversary, The British Interplanetary Society is pleased to offer a limited edition tie. This navy blue and white satin tie features the Society's comet logo.

Priced £9.50 (US$17) inc P&P

Add £1.50 (US$3) for Airmail delivery

Please send cheque/PO/ International Money Order to:

The British Interplanetary Society
27/29 South Lambeth Road, London
SW8 1SZ, England

Please allow 28 days for delivery, 4-6 weeks overseas.

SATELLITE LINK-UP

Arthur C. Clarke, a former President of the Society and originator of the idea of geostationary orbits for communications satellites, in Sri Lanka, will be brought together with Patrick Moore and other participants via a satellite link-up.

• • • • • • • • • • •

COMPLIMENTARY BUFFET

Sunday Afternoon, 17 October

Sussex Hall
White Rock Theatre

(venue of the satellite link-up)

Open to all participants courtesy of British Telecom.

SPACE INITIATIVES

Saturday 16 October

Presentations will be given by speakers from NASA, ESA, JPL, BT, DRA and Inmarsat amongst others.

Sunday 17 October

Presentations will be given by speakers from BAe, AEA Technology, ESOC and Logica amongst others.

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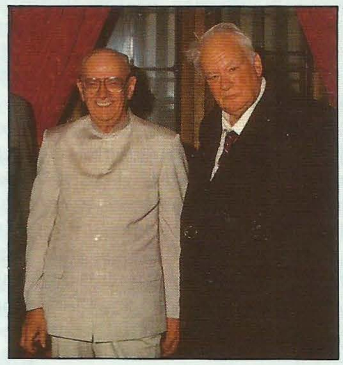
Close of Meeting

At 5pm on Sunday 17 October.

SOUVENIRS

A number of courtesy mementos are available to participants.



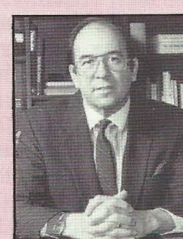
Arthur C. Clarke with Patrick Moore at a reception in London in July 1992.

ANNIVERSARY DINNER

Saturday Evening, 16 October

Marina Pavilion
St. Leonards-on-Sea

Guest speaker
Prof Garry Hunt
"After Voyager - What Next?"



Buzz Aldrin
'Questions and Answers'

Advance purchase of tickets required.

For information pack on:

- *Programme*
- *Priority Accommodation Booking*
- *Registration*
- *Anniversary Dinner Tickets*

Please contact:

**The British Interplanetary Society
27/29 South Lambeth Road,
London SW8 1SZ**

Open to Members and Non-Members. Members enjoy a discount on rates.

Correspondence

Terraforming

Sir, Dr Fiona Vincent appears to believe that the human race has "spoilt" planet Earth, so that it is no longer "truly fit to live on", and that as a result any plans we may have for making any other planets fit for life should be postponed, if not abandoned altogether (***Spaceflight***, July 1993, p.244).

I believe that we should emphatically reject such a viewpoint, and for the following reasons.

Firstly, it is simply not true that we have "spoilt" the Earth. The Earth remains now what is has been for at least the past billion years: a living planet. If we were to do any serious damage to the global biosphere, we - with our highly complex social organisation and our position at the top of the food chain - would be one of the first species to face extinction.

Secondly, although it is true that continued expansion of industrial civilisation at the present rate would indeed threaten just such serious damage, to ourselves as much as to our ecological environment, it is precisely for this very reason that we must seize the opportunity to invest in space growth now in order to relieve the future industrial pressure on the Earth.

Our children will therefore witness either massive growth in space, or else the catastrophic collapse of civilisation. Further to this point, I would strongly recommend Mark Hempsell's important article "Space Industrialisation: A New Perspective" (***Spaceflight***, July 1989, pp.224-7) - and to try to imagine what real social conditions on the streets of Great Britain and elsewhere might accompany the graphs of collapsing population and living standard shown there on the non-space projection of the future.

Thirdly, no-one to my knowledge has made any suggestion whatsoever that we are "just going to walk away from" our home planet. The Earth will continue to be the permanent home of many billions of people for the foreseeable future - in other words, for many millennia into the future, barring disruptions such as a world war or an ecological crisis precipitated by the industrial and psychological safety-valve of space expansion failing to open properly.

Fourthly, the very concepts of "spoiling a planet" and "the right to modify another planet" are totally anthropocentric ones. Nature knows nothing of such ideas, but recognises only survival, growth and decay, domination - and interdependence. The different earthly species have long been in relentless competition to pass on more of their genes to the next generation; what is remarkable about us is not that we compete against other species just like all the rest, nor even that our technology is generally better than theirs, but that some of us have the capacity to reflect upon what we are doing and to consider its long-term implications.

Most people would argue that disrupting a stable ecological balance is a bad thing, and this is implicitly one of Dr Vincent's concerns. If one day we discovered a world with a primitive but viable indigenous life, then certainly we would face a moral dilemma: conquest or restraint? But in the case of every single extra-terrestrial planetary body which we have been able to examine close up, we have found that no ecological system exists to be disrupted, and in these cases it is perfectly obvious that the moral dilemma cannot apply. Where no life exists, the concept of "spoiling" the planet is quite meaningless.

Finally, Dr Vincent states her preference for seeing terraforming techniques applied to the Earth itself. Certainly this may become necessary, either to counteract changes wrought accidentally by human industrial activity or to offset natural changes such as a renewed ice age or an increase in solar illumination.

But what must be emphasised here is that the question is not whether we terraform the Earth or some other planet instead. On the contrary, the real question is this: are we to be a civilisation capable of purposefully directing processes on a global scale, or not? If so, then we will apply those capabilities to those worlds in which we have interests. If not, then we will neither be able to affect other planets nor the Earth itself.

In conclusion, I can do no better than quote Jim Oberg's answer to the question "is it right?":

> Now, what right does humanity have to take possession of other worlds? What right? To some, the notion of Earth life expanding into the Solar System is an almost mystic crusade; to others, it is a symptom of a virulent cancer growing beyond its normal bounds. I have put this question last not because my suggested answer is the most profound part of the book, but because few people in history even get to this question. Human history demonstrates that people do what suits them and seek rationalizations afterwards. There is no reason to suspect that terraforming will be any different, or that the lack of a good answer to this question will have the slightest impact on what people choose to do on other planets. If terraforming becomes part of our future, justification will be found. (J.E. Oberg, New Earth, Stackpole, 1981, p.259).

STEPHEN ASHWORTH FBIS
Oxford, UK

ETI's Exist

I would like to take issue with a number of points made in Mr Oefner's letter in the August 1993 ***Spaceflight*** regarding the non-existence of ETI.

First, even very unlikely "accidents", such as the development of multicellular organisms from single cells, are almost bound to happen over geological timescales. If the chances of a certain event occurring in any given year are only one in a million, the probability of that event occurring at least once in a 5 million year period is over 99 per cent. Furthermore, when such improvements in the design of an organism do occur, natural selection makes it very likely that the improvement spreads rapidly through the population, thus making it permanent and a foundation for further improvements. In the case of the nervous system, an organism that can see, hear, learn, think and act just a little better than its prey or its predators has a great selective advantage, all else being equal. Thus, the emergence of at least one intelligent species is a likely (though not certain) consequence of evolution in the long run.

Analogous reasoning applies to the development of technology by intelligent beings. A particular invention or discovery might require an act of brilliant genius on the part of one individual, and as such is very improbable. But once somebody has a good idea, and puts it into practice, the knowledge can spread throughout the culture, and become the basis for further discovery. Thus, each discovery only needs to be made once, or at most a few times. Again, it is not inevitable that intelligent life will develop technology (consider the dolphins), but it is not wildly improbable.

Mr Oefner also argues that any ETIs in our neighbourhood are likely to be either much less advanced than us, in which case they are barely intelligent at all, or much more advanced than us, in which case they should be capable of making their presence obvious. I agree with this argument, but it does not imply that ETIs do not exist. There are many conceivable reasons why they might not want to talk to us. They might consider it unethical to interfere with primitive cultures; they might be worried about the consequences of giving us access to their vast knowledge and power (like giving fireworks to a small child); or their minds might simply be on more important matters.

I think ETIs exist, but I also think that as a species we are going to have to mature a bit before they allow us to join the "Galactic Club"!

MARTIN EBDON
East Sussex, UK

Nonclassical SETI Needed

Sir, All current projects [1] to search for extraterrestrial intelligence (SETI) are based on the postulates of G. Cocconi and P. Morrison [2]:

(a) extraterrestrial beings want to communicate with our civilisation;
(b) electromagnetic waves are the most convenient mode for transmitting information;
(c) artificial emission must be narrowband, variable, repeating and have a point source identified with some solar-like star.

Most radio and optical (laser) SETI-projects are an embodiment of these classical assumptions. However, they reflect only one variant from a wide spectrum of possibilities. Intelligent life may occur near stars of many types (and also elsewhere) if one provides an artificial environment for life support. A radio source consisting of a great number of radio transmitters could appear wideband and extended. Repeating signals seem improbable in the case of the accidental interception of a narrow transient radio beam. Moreover, an advanced alien civilisation could secretly study us by radio monitoring without replying. Also, electromagnetic waves are not a uniquely convenient communication tool.

Many such possibilities are not taken into account in most SETI-programmes. As a result of the predominance of the classical approach, we have several expensive, very chancy and inconclusive experiments planned. Therefore, the parallel development of nonclassical SETI-projects appears reasonable. The search for alien artifacts in the Solar System [3], the study of unusual radio sources [4], and the exploration of unidentified cosmic sporadic radio flashes [5] seem to be promising examples of nonclassical possibilities. Unfortunately, such alternatives are ignored by influential experts who, as a rule, are involved in the well-financed classical SETI-projects.

But is it not more reasonable to search for the "needle", as the ETI evidence (signal) is often called, not in the "cosmic haystack" but on some sky "magnet"? The Moon, as a convenient base for monitoring our rare inhabited planet, appears to be a likely "magnet" for alien artifacts [6]. This is a problem that is being analysed intensively in the Research Institute on Anomalous Phenomena in Kharkov, Ukraine, as the SAAM project (SAAM - Search for Alien Artifacts on the Moon).

The choice of an optimum SETI strategy *à priori* is hardly possible. Hence, it is naive to rely on the classical approach only. Even supermodern equipment would be useless in a search being carried out along unsuitable lines and could lead to failure, scepticism and withdrawal of financial support.

A.V. ARKHIPOV
Institute of Radio Astronomy,
Kharkov, Ukraine

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1. R. Naeye, *Sky and Telescope*, **84**, No. 5, p.507, 1992.
2. G. Cocconi and P. Morrison, *Nature*, **184**, No. 4690, p.844, 1959.
3. R.A. Freitas, JBIS, 36, No.11, p.501, 1983.
4. A.V. Arkhipov, in Bioastronomy - The Next Steps, G. Marx (ed), Kluwer Academic Publishers, Dordrecht, p.337, 1988.
5. A.V. Arkhipov, in Bioastronomy. The Search for Extraterrestrial Life - The Exploration Broadens, J. Heidmann, M.J. Klein (eds.), Springer-Verlag, Heidelberg, p.244, 1991.
6. A.V. Arkhipov, *Selenology*, **12**, No. 1, p.6, 1993.

First Manned Spaceflight

Sir, Until now not all circumstances of Gagarin's space flight have been clarified although several facts were published because of the 30th anniversary in April 1992. You reported in the July edition of ***Spaceflight*** on CIA documents about Soviet space travel and the manned Soviet space programme but the Vostok flights were not mentioned.

Many speculations on the space flight of Gagarin came up after the publication of Istvan Nemre's book ('Gagarin - die kosmisch Lüge'). Not all of his notes are unrealistic although one can assume that Gagarin flew in April 1961. But some facts refer to a manned launch before Gagarin. The USSR tried to prevent by all possible means the USA from launching the first man. The possibility existed that after the successful launch of Mercury-Atlas 3 and Mercury-Atlas 5 at the end of 1960 an advanced manned launch of a Mercury capsule with at least one orbit could have taken place in early 1961.

It has been revealed that a Vostok capsule landed in a remote region in the east of the former USSR after a failed launch and was urgently looked for. This happened on 21 December 1960 and supports the theory of a failed attempt of the USSR to launch the first man into space. During this operation the cosmonaut (Ilyushin?) could have been injured so badly that he had to be taken out of the programme or even died. Officially the reason given for Ilyushin's death was a traffic accident.

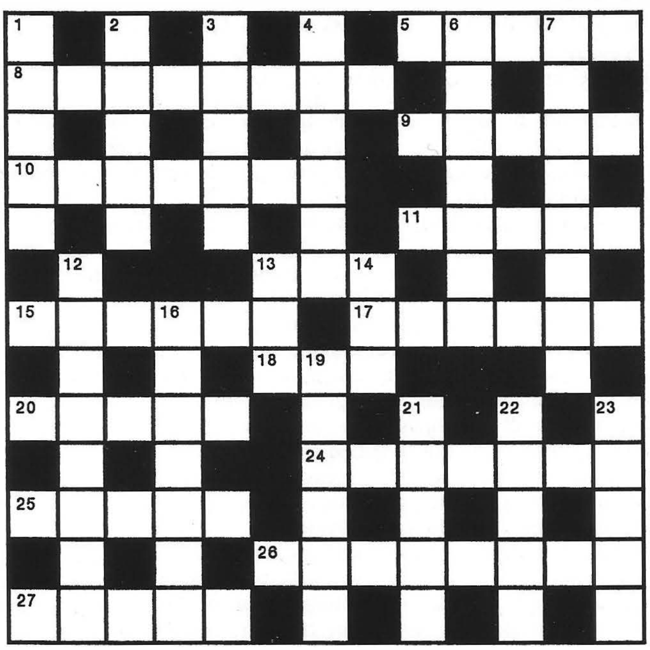
The original flight plan of the USSR was to launch a manned spacecraft in December 1960. Was it only cancelled because of the explosion of the Mars rocket? After this event Korolyev might have convinced Khrushchev to alter the flight profile. The flight was not to be limited to one orbit and the cosmonaut would land with a parachute outside the Vostok capsule. After a long break two test flights took place in March 1961 with the new flight profile. This also explains the numbering Vostok 1A, 2A and 3A (1A and 2A are used for the new flight profile and 3A is used for Gagarin's launch).

A. FELLENBERG
Essen, Germany

The Editor welcomes items of correspondence for publication. The right is reserved to shorten material as appropriate.

Spaceflight Crossword

No. 2



ACROSS
5 Redesigned urban shuttle ?
8 Interplanetary traveller
9 Nibbles for a hungry computer
10 A come down for a spacecraft (2-5)
11 Satellite with a film award?
13 ESA's first communications test satellite of 1978
15 ESA's communication satellite series on station from 1981
17 Passed quality control
18 Hz
20 Arrive at
24 Aerial
25 Gradient
26 Geostationary weather satellite series
27 Target for electrons

DOWN
1 A star satellite ?
2 Moon decreases in size
3 Greek booster, alphabetically speaking
4 Space station
6 Mythological Sun probe
7 Law of ———
12 Circumnavigator at Venus
13 Makers of Pegasus booster
14 Sits eyeless, on the launch pad perhaps?
16 Reached more than 11 km/s
19 Wandering star to ancient astronomers
21 Space to the anaesthetist
22 Occupied (2,3)
23 Speedy

Solution will appear in the November issue.

Solution to Crossword No.1. **ACROSS:** 1. Helen; 4. Sharman; 8. Remote; 9. Lunar; 11. Zenit; 12. Rosetta; 14. Even; 16. No; 17. ESA; 18. CIS; 20. If; 23. Noel; 25. Alerted; 27. Lifts; 29. Incur; 30. Ignite; 32. Landsat; 33. Light.

DOWN: 1. Horizon; 2. Lemon; 3. Nutates; 4. SF; 5. Atlas; 6. Minute; 7. Nerva; 10. Ore; 13. Once; 15. Vane; 19. Illegal; 21. Fastest; 22. Beacon; 24. Odd; 25. Ariel; 26. Tiros; 28. Fling; 31. ET.

BOOK NOTICES

These notices, compiled by L.J. Carter, are not intended to be reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

Full publication details are given for each book to enable copies to be ordered from a local bookseller, if desired. The address of each publisher also appears, for many items can now be ordered direct from them. If not, they will supply the address of a local agent who can handle matters.

Collecting the Space Race

S. Schneider, Millbank Books Ltd., Victorian Wing, Rawdon House, High Street, Hoddesdon, Herts., EN11 8TE, 1993, 176pp, £34.95.

Collecting space souvenirs is attractive not only to "space buffs" but to the wider range of ordinary people who throng every Space Centre open to the public.

This book explores such artifacts or memorabilia, starting from the beginning of the 20th century. The author has collected such unusual items for 30 years and has drawn heavily on his collection for the vast numbers of coloured illustrations featured in these pages. He includes items relating to original Mercury flights, Sputniks, Man on the Moon items, satellites, space theme postage stamps and Mission Patches, as well as a wide range of fantasy items e.g. ray guns, space toys, etc.

At first sight, this blend of fact and fiction might seem to detract from the book in the eyes of an otherwise "serious" collector but this is unlikely to be so in practice for most readers who obtain a copy will be intrigued by its content and consider it a unique version of the many books on collectables which appear nowadays. This one, however, has the added advantage that it features many collectables which are still available at modest prices and helps to give a clearer view of the intrinsic interest of the many newer items which have since come on to the market.

Members of the Society who order direct from Millbank Books can claim a 10% discount and free postage and packaging.

The Dream Machines: An Illustrated History of the Spaceship in Art, Science and Literature

R. Miller, Krieger Publishing Co., PO Box 9542, Melbourne, FL 32902-9542, USA, 1993, 744pp, $112.50.

The volume, by a Fellow of the Society, portrays the history of the spaceship both as a cultural and technological phenomenon. The concept of a vehicle for travelling between worlds did not come full-blown into existence during the latter half of this century but was preceded by thoughts on space travel spanning hundreds of earlier years. As soon as it was realised that there were other worlds than the Earth, there were some who thought about how such a journey could be made.

Tracing the history of the multitude of imaginative attempts to try to solve this problem over a period of about 2000 years or so, involves the history of technology, science, astronomy and engineering, for once the idea of space travel became feasible, more spacecraft concepts were developed than ever got off the ground. These, too, are included in this book, for they all reflect the dreams, abilities and knowledge of a particular era.

Virtually every spaceship concept put forward since 1500, besides events important in developing the idea of extraterrestrial travel, appear in chronological order, an approach which allows easy comparison to be made between actual astronautical events and speculative ventures. It also allows comparisons between simultaneous events in different countries and reveals connections, influences and evolutions which might otherwise not be appreciated. Every entry is accompanied by at least one illustration, so nearly every spacecraft concept is illustrated with a schematic drawing.

The text is bound to interest students of astronautical history. It features a unique collection of nearly 1,000 illustrations reproduced in two colours throughout, which make it both visually attractive and a most interesting account of the history of the spaceship.

Origin and Evolution of the Elements

Eds. N. Prantzos, E. Vangioni-Flam and M. Casse, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1993, 545pp, £45.

The task of astrophysics is to observe the universe and its components and to use the laws of physics to try to understand the origin and evolution of the cosmos as a whole, as well as of its individual components. This involves the relationship between the universe and its structures e.g. bodies such as galaxies and galactic clusters, stars and star clusters, planets and similar systems on the one hand, and physical laws such as quantum mechanics, relativity and gravity on the other, for all are needed to contribute to our understanding of how the universe evolved.

Most objects in the universe seem to have a more or less similar chemical composition, dominated by hydrogen and helium, a fact which points quite clearly to their common origin and which is underlined by the realisation that the energy sources of the Sun and stars transform the lighter elements into heavier ones. This is why the study of the formation of the cosmic elements in various astrophysical bodies has attracted researchers from astrophysics, nuclear physics, meteoritics and many other disciplines.

Stellar and primordial nucleosynthesis, cosmic rays and other processes involved in the formation of cosmic elements are discussed and recent observational data is presented on the abundance of astrophysical objects. Several review articles summarise current knowledge while others address more topical issues.

The Anthropic Principle

F. Bertola and U. Curi, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1993, 181pp, £30.

The Anthropic Principle states that the Universe around us possesses all the conditions and attributes we observe simply because *we* are here. Out of all possible Universes, we can only experience the one we see. If this is really so, then it has profound implications on our views of cosmology, philosophy and theology, all of which are subject areas of interest in this book.

Sixteen contributors discuss their theories on the subject within a scientific context and endeavour to elucidate man's role in the universe, beginning with the premise that, whether man is important in the scheme of things or not, the universe he sees should have properties compatible with his powers of observation, for he can only exist in that special universe whose properties are compatible with his existence. In other words, is the existence of life an indispensable condition for the existence of the universe?

This is very much a book for theorists and for those who ponder about why the universe is as it is.

Reaching for the Stars: The Illustrated History of Manned Spaceflight

P. Bond, Cassell, Villers House, 41/47 Strand, London, WC2N 5JE, 1993, 128pp, £15.99.

More than 250 men and women of many different nationalities have ventured into space since the flight by Yuri Gagarin in 1961.

This book not only recounts a story which is of absorbing interest but also describes the massive technological investment required by space programmes besides the epoch-making events that marked the rivalries i.e. the Cold War, concluding with an account of potential future developments.

The illustrations are excellent and the text very clear and absorbing.

Stellar Photometry - Current Techniques and Future Developments

C.J. Butler and I. Elliott, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1993, 369pp, £35.

Stellar photometry from space using automatic photometric telescopes and CCD photometers are just some of the areas of current interest which have an exciting potential for future developments. It is an area which is fundamental to the measurement of stellar parameters and, increasingly, to the study of the atmospheres and interiors of stars.

In this book a series of articles discuss the current state-of-the-art of all aspects of stellar photometry and provide a guide to future developments. Its wide-ranging contents include:

Photometric systems - the effect of detector choice
High-Precision photometry - routine millimagnitude accuracy
New techniques - multichannel arrays in optical and IR photometry
Automatic photometric telescopes - setting up a global network
CCDs - time-series photometry of faint sources
Photometry from space - the Wide Field Camera and the High Speed Photometer on the Hubble Space Telescope

It gives an excellent survey of the factors involved in the design and use of these instruments.

RAE Table of Earth Satellites

Defence Research Agency, Farnborough, Hants, UK, GU14 6TD.

Work on updating the RAE Table of Earth Satellites has now been discontinued so the supplement for 1990/1992 will now be the final issue. Copies of the Table for 1957-1989 are still available and now at the reduced price of £50, including postage and packing (£65 overseas). This price also includes the 1990/1992 supplement.

The DRA Table of Space Vehicles (Eds. A.N. Winterbottom and G.E. Perry) for 1958-1991 is also available for £30 from the same source. This is a companion to the Earth Satellite Table and lists all 124 space vehicles to escape from Earth over the 1958-1991 period, with an additional chapter giving details of the two 1992 launches. Data features the name and international designation of each satellite and its associated rocket(s), launch date, mass, shape and size and details of orbit or trajectory. Where appropriate, the time and place of impact or landing on the Moon or planet are given. There is also an 11 page foreword with mission information, an introductory guide to the tables and a chapter describing interplanetary launch vehicles.

'Space Dates' Competition

A still from the 1950 Technicolor Film *'Destination Moon'*. Publicity for the film proclaimed 'It's closer than you think!' and 'Know how it feels to fly to the Moon!'.

The first prize offered with this month's competition is a copy of:

The Dream Machines:

An Illustrated History of the Spaceship in Art, Science and Literature

by BIS Fellow Ron Miller

Special features of the book are scale drawings of several hundred spacecraft, both real and fictional, and scores of illustrations. See Book Notices opposite for further description and publication details.

Four Consolation Prizes are offered of the book

Citizens of the Sky

by BIS Fellow Robert C. Parkinson

The prizes will be awarded to entries with the most correct answers and will be decided by a draw in the case of a tie.

ENTRY FORM

Title/Name ....

Address ....

....

....

To Enter: Put a circle round the year in which:

1.	Jules Verne published his novel *From the Earth to the Moon*	1865	1870	1875
2.	H.G. Wells published his novel *First Men in the Moon*	1891	1896	1901
3.	Percival Lowell published *Mars and its Canals*	1906	1916	1926
4.	K.E. Tsiolkovsky published *The Space Rocket: Experimental Development*	1907	1917	1927
5.	Robert H. Goddard took out patents for both liquid-fuelled rockets and the step-rocket	1915	1925	1935
6.	The first successful launch of the A4 (V2) took place	1938	1940	1942
7.	Arthur C. Clarke published *Interplanetary Flight*	1950	1955	1960
8.	***Spaceflight*** was first published	1956	1958	1959
9.	Valentina Tereschkova became the first woman to fly in space	1963	1965	1967
10.	Apollo 1 caught fire on the launch pad	1965	1966	1967
11.	Soyuz II and Salyut I docked to become 'the first orbiting scientific laboratory'	1971	1974	1977
12.	The Apollo-Soyuz Test Project took place	1975	1978	1981
13.	Space Shuttle *Columbia* made its first orbital flight	1978	1981	1984
14.	The initial presentation of the HOTOL spaceplane was made	1984	1986	1988
15.	Soviet shuttle *Buran* made its first orbital flight	1986	1987	1989

Post to: The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ to arrive by first delivery on 4 November 1993.

Launch Report

DC-X Tests Underway

On 18 August the Delta Clipper-Experimental rocket (DC-X) impressively passed its 'hover' tests by roaring to a height of 150 feet and moving 350 feet to one side before touching down, nose uppermost, on its landing pad.

The 42-foot tall DC-X is a one-third scale prototype of McDonnell Douglas' proposed Delta Clipper (***Spaceflight***, March 1993, pp.90-94).

The next test to be undertaken shortly will be the first flight test proper with the vehicle climbing to 8 km altitude.

DC-X suborbital vehicle. *McDonnell Douglas*

Replacement Study Follows Mars Observer Loss

NASA is looking into the possibility of sending another space probe to Mars even while experts are studying Mars Observer's puzzling disappearance. A group of experts already assembled will attempt to determine whether the spacecraft exploded, went into orbit around the planet, continued on its outward journey or simply had a radio failure.

On 21 August, communications were lost with the Mars Observer spacecraft as it approached to within 3 days of the planet Mars. Engineers and mission controllers at NASA's Jet Propulsion Laboratory (JPL) responded with a series of backup commands to turn on the spacecraft's transmitter and to point the spacecraft's antennas toward Earth, but no signal from the spacecraft was received by tracking stations around the world.

Commands were issued every 20 minutes instructing the spacecraft to switch to a wider beam low-gain antenna and radio its status back to JPL.

Mars Observer had an on-board sequence that would issue the proper commands to execute the critical Mars orbit insertion events on 24 August, assuming that the spacecraft was operating properly. This on-board sequence was designed to assure that the spacecraft would be captured into Mars orbit even if ground controllers could not communicate with it.

Communications were lost at the time that the tanks in the propulsion system were being pressurised and the possibility exists that the craft may have self-destructed. However NASA has no reason to believe that the propulsion system did not properly pressurise and suspect defective transistors may have crippled the craft.

The probe was expected to give the most detailed picture yet of the Martian landscape and was considered to be an essential precursor to a manned mission to Mars planned for early next century. The project included scientists from Britain, France, Germany and Russia. After completing its primary mission, Mars Observer was to help relay data from the Mars 94 Russian landing craft in 1995 and from a French exploration balloon and Russian robot rover during the Russian Mars 96 mission in 1997.

The data that was to have been obtained from Mars Observer is vital before any plans can be made for landing robots or humans on the planet. It remains the top priority for NASA. The agency had planned to land the first of a network of ground stations on Mars in 1996 in a project called MESUR (Mars Environmental Survey) - see ***Spaceflight***, June 1993, p.209. That project may now be put on hold or adapted to fly some of the Mars Observer instruments. Originally, NASA had planned to build a second Mars Observer in case the first one failed but did not do so for lack of money. Some duplicate instruments and components were built and could be used on a substitute mission.

A new mission, if there is one, will be at a far lower cost and may involve the participation of other nations. NASA Administrator Daniel Goldin has named a team to explore possibilities for another mission, using a variety of low-cost spacecraft, instrument and launch options. A decision on a replacement mission must be made soon since the next best launch opportunity is next year and then in 1996. The team's report is due in two months.

SPACE PROBE DIARY

1 September 1993

Galileo

An encounter with asteroid Ida was successfully completed by the Galileo spacecraft on 28 August after approaching to within 2,400 km of the asteroid which is about 32 km long by 28 km in diameter. Preliminary analysis has verified the presence of an Ida image on tape. Playback at 40 bits per second will continue until late September and then resume in the Spring of 1994. Galileo will go into Jupiter orbit and operate a probe in its atmosphere on 7 December 1995. Galileo was launched 18 October 1989, flew by Venus in 1990 and Earth in 1990 and 1992 for gravity assists, and flew by asteroid Gaspra in October 1991.

Ulysses

The spacecraft is in a highly inclined solar orbit, now about 38 degrees south relative to the Sun's equator, and in transit from its Jupiter gravity assist in February 1992 toward its solar polar passages (at about 80 degrees south and north) in 1994 and 1995. Spacecraft condition and performance are excellent with data being gathered on the heliosphere - the realm dominated by the solar wind. The Ulysses spacecraft was built by ESA and launched on October 6, 1990.

Voyager 1 and 2

The two Voyager spacecraft are continuing their Interstellar Mission having remotely detected the heliopause, the boundary between the solar magnetosphere and interstellar space, for the first time recently. Voyager 1, launched on 5 September 1977, is currently 8 billion km from the Sun after flying by Jupiter and Saturn in 1979 and 1980; Voyager 2, launched on 20 August 1977, to fly by Jupiter (1979), Saturn (1981), Uranus (1986) and Neptune (1989), is now more than 6 billion km from the Sun.

Atlas Launch of Navy Satellite

On 3 September an Atlas rocket launched from Cape Canaveral successfully placed a US Navy satellite in orbit. The satellite is the second of nine communications satellites ordered by the Navy from Hughes Space and Communications. The launch was especially crucial as the first satellite was left in a useless orbit last spring by an Atlas. General Dynamics grounded its Atlas rockets for four months as a result of the failed mission, which was blamed on a loose engine screw.

This mission lifted off 18 minutes late because of a ground-equipment glitch within an 80-minute launch window. The satellite, called UHF Follow-on F-2, is expected to come into use in mid-November once it has been positioned 22,300 miles above the Indian Ocean.

The F-2 satellite is a Hughes HS 601 model. The UHF Follow-on satellites will replace the existing constellation composed of Leasat and Fleet Satellite Communications vehicles.

US and Russia to Sign Major Space Agreement

The United States and Russia plan to sign agreements involving space, missile technology and energy issues, which were reached in meetings on 1 and 2 September between Vice President Al Gore and Russian Prime Minister Viktor Chernomyrdin.

The new agreements are expected to pave the way for sweeping developments in joint US-Russian launch and in-space activities. The design for a new US space station called Space Station Alpha has now emerged from the discarded plans for Space Station Freedom. It will rely on Russian spacecraft for "lifeboats" and probably for steering. To limit costs, the construction will be stretched out and the station will not be ready for permanent occupancy until the year 2003 - three years later than previously planned.

Teams from the two nations were involved in a series of intense and often lengthy meetings as part of a working conference of the new US-Russian Joint Commission on Energy and Space, which was created at a Vancouver meeting between President Bill Clinton and Russian President Boris Yeltsin last February.

The follow-on US-Russian discussions were then postponed from last Spring after the US administration protested at Moscow's sale of rocket technology to India. New assurances from the Yeltsin government paved the way for the Washington meetings and the two leaders have now agreed to meet at least two or three times a year.

The new plan involves attaching two Soyuz craft to the station as "assured crew return vehicles". It also favours using the Russian Salyut space tug for steering the station, instead of a US propulsion module. The plan includes 19 flights to bring the station to the point, in 2003, when it can house four astronauts permanently.

The first assembly flight is to be in 1998 and the station will be ready after flight four for use by visiting astronauts in 1999. They will live aboard the space shuttle while working on experiments in the Alpha laboratory. The station design calls for an orbit no farther north than Cape Canaveral and no farther south than Chile and Argentina, but it will have to be changed to accommodate the Russians who can only launch into orbits that go over southern Canada in the north and New Zealand in the south. The station will consist of a single beam truss on which various modules will be mounted.

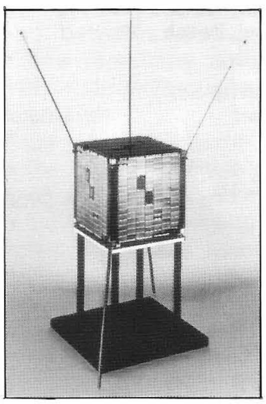
If all goes according to plan, the completed station by 2003 will have a US laboratory and US living quarters, a Japanese experiment module, an ESA pressurized module and a Canadian mobile servicing system, including a multihanded robot arm. Solar power panels will be located at the ends of the beam, and they will follow the Sun through rotating joints. The station will have at least 30 kW of electricity available for users, about half of what was planned for Freedom.

First Russian Launch of a Western Satellite

TEMISAT (TElespazio MIcro SATellite) was successfully launched piggyback with a Russian satellite on 31 August. TEMISAT was attached to the payload platform of the Russian METEOR-2 weather satellite which was launched by a CYCLON rocket from Plesetzk. After reaching its nominal orbit, following separation from the main carrier, early orbit check-out operations started, the first signal from TEMISAT being received on 1 September by the Fucino ground station in Italy.

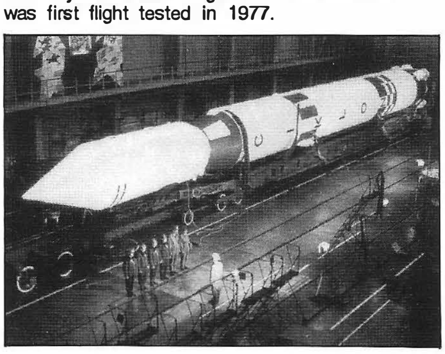
This 50-kg satellite represents the first commercial venture in Europe to use lightsat technology for digital communications with small terminals. It will be used to offer Data Collection and Distribution Services for environmental monitoring around the Mediterranean Sea. The TEMISAT budget covering the launch of the first lightsat is just $10 million.

TEMISAT was developed and built by Kayser-Threde under contract to the Italian satellite operator Telespazio.



TEMISAT satellite. *Kayser-Threde*

The Cyclon three-stage launch vehicle which was first flight tested in 1977.



— Comment —

Space Station 'Equal Partner' Status in Doubt

The recent US-Russian announcement on joint space activities could have important implications on the direction of future European space policy.

The ESA Member States have been buffeted by previous changes in the United States' attitude since they accepted President Reagan's offer to join as "equal partners" in Space Station Freedom. Each twist and turn has cost Europe considerable sums of money in design changes, delays, and the lack of a clear way ahead. Morale in both the industrial team and the ESA team has naturally been affected adversely.

The latest move, which reduces Europe, Japan and Canada to a much lower level than "equal partner", despite Vice-President Gore's statement otherwise, could well trigger a strong reaction from the ESA Member States, who will not have forgotten the Spacelab experience.

What will now be on offer to other "partners" is that of fulfilling a minimal role by providing an "add on" to a core station, with a later launch date of 2002 at the earliest. The ESA Member States may consider it to be too steep a price to pay for such a second level partnership position.

It also has to be recognised that only limited studies and costings have been carried out and experienced engineers on all sides remain sceptical of what the new developments will entail.

For these reasons serious doubts must exist about whether such a compromise space station will ever come about.

There is also the possibility that Congress will use this shift from the development of the Space Station Freedom approved by President Clinton to a joint US-Russian activity as an excuse to re-open attacks on the whole concept of manned space flight.

Titan 4 Fails

A Martin Marietta Titan 4 rocket exploded 101 seconds after liftoff on 2 August.

Martin Marietta Enquiry

Within one three-week period in August, Martin Marietta saw one of its rocket (a Titan 4) explode and two of its spacecraft (Mars Observer and a weather satellite) lose contact with Earth. Both spacecraft were built by GE Aerospace before Martin Marietta bought the General Electric Company division for $3 billion in March. Martin Marietta Corporation is now undertaking an internal investigation.

SATELLITE DIGEST-257

Satellite Digest is our regular listing of world space launches. It is abridged from a more detailed monthly listing, Worldwide Satellite Launches prepared by Phillip S. Clark and published by the Molnlya Space Consultancy.

Spacecraft	Int'l Desig.	Launch	Launch Site	Launch Vehicle	Mass kg	Orbital Epoch	Inclin. deg	Period min	Perigee km	Apogee km	Notes
Soyuz-TM 17	1993-043A	Jul 1.61	Tyuratam	Soyuz	7,150 ?	Jul 3.85	51.62	92.39	388	395	[1]
Cosmos 2258	1993-044A	Jul 7.30	Tyuratam	Tsyklon-M	3,000 ?	Jul 7.55	65.05	92.78	404	418	[2]
Cosmos 2259	1993-045A	Jul 14.69	Plesetsk	Soyuz	6,500 ?	Jul 16.24	67.12	89.99	170	366	[3]
DSCS-3B 3	1993-046A	Jul 19.92	ER	Atlas-2	1,040 ?	Jul 24	0	1,435.1	35,768	35,768	[4]
Cosmos 2260 ?	1993-047A	Jul 22.37	Plesetsk	Soyuz	6,300 ?	Jul 23.10	82.29	89.89	241	297	[5]
HISPASAT 1B	1993-048A	Jul 22.96	Kourou	Ariane 44L	2,210	Jul 30.25	0.01	1,431.01	35,604	35,771	[6]
INSAT 2B	1993-048B				1,931	Jul 24.07	1.19	911.20	13,782	35,730	[7]

NOTES

1. Three manned spacecraft carrying Russian cosmonauts V V Tsibylev (commander) and A A Serebrov (flight engineer) with third French spationaut J-P Haigneré to the Mir Orbital Complex: mission includes experiments under the French *Altair* programme. Docked at the front longitudinal port of Mir 1993 Jul 3.68 (16.24 GMT). Russian cosmonauts are due to remain in orbit until November-December 1993, Haigneré returned to Earth 1993 Jul 22 aboard Soyuz-TM 16 (1993-005A) - see details below. Actual launch time 14.33 GMT.

2. Third launch of an ELINT Ocean Reconnaissance Satellite (EORSAT) in 1993. Orbit is co-planar with those of Cosmos 2238 (1993-018A) and Cosmos 2244 (1993-029A).

3. Fourth generation, close look photoreconnaissance satellite. Spacecraft was expected to release some data return capsules during its mission with the main re-entry module returning to Earth after about 60-65 days. Instead the satellite disappeared from orbit 1993 July 29 after less than two weeks in orbit. The short lifetime is indicative of a problem developing with the satellite which prevented the complete mission from being undertaken. Actual launch time 16.40 GMT.

4. Third improved Defense Satellite Communications System satellite of the third generation to be launched. Orbital data for the satellite not released by USSPACECOM and the orbits above are based upon those quoted in *Aviation Week & Space Technology*. Actual launch time 22.04 GMT.

5. Confusion arose over the name of this satellite: separate Russian launch announcements called it "Cosmos 2260" and "Resurs-T" (the latter being a new satellite designator), while USSPACECOM called it Resurs-F 19. Remote sensing satellite, based upon the Vostok spacecraft design. Actual launch time 08.56 GMT.

6. Spanish telecommunications satellite: planned operational longitude is over 270 °E. Actual launch time 22.59 GMT.

7. Indian communications and remote sensing satellite, planned for deployment over 83 °E. Launched with HISPASAT 1B.

ADDITIONS AND UPDATES

1967-043B Hitchhiker 14/OPS 1967 decayed 1993 Mar 14.

1973-100B During Mar 11-14 DSCS-2 4 was boosted off-station in geosynchronous orbit and has possibly been retired.

1978-113A During late April and early May DSCS-2 11 was boosted off-station in geosynchronous orbit and has possibly been retired.

1984-049A Following its orbital relocation from 239 °E to 115 °E, Spacenet 1 is being operated by the China Communications Broadcasting Satellite Company and has been re-named "Star of China 5".

1983-113B At the beginning of April Anik-D 1 was manoeuvred off-station and since the orbit has not been re-stabilised the satellite has probably been retired.

1992-078A MSTI decayed from orbit Jul 18.

1993-005A Soyuz-TM 16 undocked from the Mir Complex (Kristall module) Jul 22 and landed 140 km east of Dzhazkazgan Jul 22.28 (06.42 GMT). Returned with Russian cosmonauts G M Manakov and A F Polishchuk (launched aboard Soyuz-TM 16) and French spationaut J-P Haigneré (launched aboard Soyuz-TM 17).

1993-015A Add another orbit for UHF 1: Jun 1.52, 27.31°, 1,450.90 minutes, 36,069 km, 36,083 km.

1993-026A Telemetry is now being received from ALEXIS following previous problems with the communications system.

1993-031B Add a further orbit for Arsene: Jun 20.50, 1.12°, 1,012.66 minutes, 17,186 km, 36,867 km.

1993-034A Progress-M 18 undocked from the Mir Complex (front transfer compartment) Jul 3 and was de-orbited Jul 4. During the spacecraft descent a Raduga recoverable capsule was ejected and this landed Jul 4.71 (17.05 GMT).

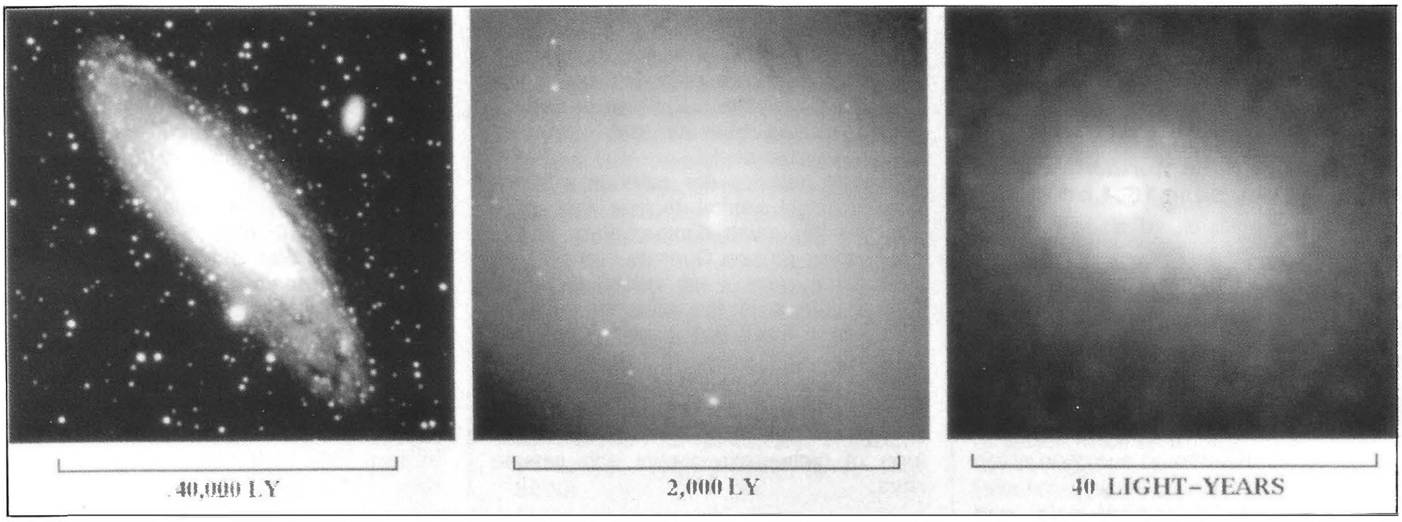
1993-039A Add further orbital data for Galaxy 4: Jul 3.46, 0.14°, 1,437.13 minutes, 35,689 km, 35,924 km, and Jul 4.46, 0.12°, 1437.03 minutes, 35,700 km, 35,910 km.

1993-040A Add further orbital data for Resurs-F 18: Jul 3.01, 82.59°, 89.08 minutes, 223 km, 235 km and Jul 7.04, 82.59°, 89.09 minutes, 223 km, 236 km. Descent module was recovered approximately Jul 12.2.

1993-042 The launch time for Navstar 21 was 13.27 GMT. Add the following orbital data: Jul 3.64, 54.74°, 717.20 minutes, 20,085 km, 20,242 km and Jul 16.59, 54.74°, 717.96 minutes, 20,161 km, 20,243 km, 292°.

Astronomical Notebook

Double Nucleus in the Andromeda Galaxy



***Left:** Ground View of Galaxy Core:* One of the closest neighbours to our own Milky Way galaxy, M31 (the 31st object in a catalogue of non-stellar objects compiled by French astronomer Charles Messler in 1774) dominates the small group of galaxies of which our own Milky Way is a member. M31 can be seen with the naked eye as a spindle-shaped "cloud" the width of the full moon.

***Centre:** Ground View of Galaxy Core:* The nucleus is at the centre of the bulge of M31, a smooth system of old stars. The bulge is apparent as the bright centre of M31 in standard pictures of the galaxy. Individual points of light are globular star clusters each containing several hundred thousand stars. This ground-based telescopic image does not resolve the double nature of the nucleus. The background of the present picture is dark only because the contrast has been adjusted to show the full detail of the nucleus, which is much brighter than the surrounding bulge.

***Right:** HST View of Galactic Nucleus:* A NASA Hubble Space Telescope (HST) image of a "double nucleus" in the giant spiral galaxy in Andromeda, M31. Each of the two light-peaks contains a few million densely packed stars. The brighter object is the "classic" nucleus as studied from the ground. However, HST reveals that the true centre of the galaxy is really the dimmer component. This green-light image was taken with HST's Wide Field and Planetary Camera (WF/PC), in high resolution mode. The two peaks are separated by 5 light-years. The Hubble image is 40 light-years across. *T.R. Lauer (NOAO), NASA*

It seems that the M31 nucleus is much more complex than previously thought and that the brighter member might be the remnants of another galaxy cannibalised by M31, though an alternative possibility is that a dust cloud has dimmed the core to create the illusion of a pair of separate star clusters. Even so, neither interpretation offers a complete explanation of the M31 nuclear structure.

HST pictures show two bright spots at the heart of the M31 galaxy. The dimmer of the two "light-peaks" appears to mark the exact centre of the galaxy. The brighter peak is at least five light-years away from the true centre but corresponds to what astronomers had previously thought from ground-based observations *was* the nucleus of M31.

M31 is 2.3 million light-years away and is the nearest major galaxy to our own Milky Way. It dominates the small group of galaxies (of which our own Milky Way is a member), and is visible to the naked eye as a small "cloud".

Like the Milky Way, M31 is a giant spiral-shaped disk of stars, with a bulbous central hub of older stars. It has long been known to have a bright and extremely dense grouping of a few million stars clustered at the very centre of its spherical hub but, as seen from ground-based telescopes, the starlight blends to resemble a single bright almost point-like source, so previous ground-based observations gave little hint of the true structure of the core.

Cannibalised Galaxy ?

One possible explanation for the second cluster being offset from the exact centre is that it is the remnant of a smaller galaxy that fell into M31, perhaps a billion or so years ago, with the smaller galaxy's core as the only surviving fossil relic of the galactic collision.

A problem with this scenario is that the remnant core should be torn apart by the massive black hole hypothesised to dwell at the exact centre of M31. The suspected black hole would be located in the middle of the dimmer peak uncovered by HST.

The first evidence for a black hole at the exact centre of M31 came from ground-based observations in 1988, indicating an abrupt increase in the orbital velocities of stars in the centre of the M31 nucleus.

This led to the conclusion that M31 must have a strong, but unseen, concentration of mass at its centre. A black hole, at least ten million times the mass of the Sun, is the most likely type of object matching these characteristics.

Dust Lane Bisecting the Nucleus ?

Another interpretation of the "twin peaks" is that the bright spot is just the outer portion of a large star cluster nucleus and that the central portions have been obscured by dust. A thick ring of dust might even cut across the nucleus, creating the illusion of two separate objects rather than one elongated structure.

The problem with this idea is that normal galactic dust would scatter the light so that it would appear reddened but, in this case, there are no colour effects at all.

Mini Asteroid Belt

The Earth's chances of being hit by objects up to 150 feet across could be 10 to 100 times greater than previously believed, say the University of Arizona's Spacewatch programme teams who have detected more than 40 asteroids in the Earth-Moon neighbourhood since observations began in January 1991. Thirteen were less than 160 feet in diameter, which indicates the presence of a mini asteroid belt.

Their findings do not mean an increased probability of major damage on the Earth's surface for, although small asteroids may enter the atmosphere with the energy of a 10-megaton bomb (the equivalent of 10 million tons of TNT), they would probably explode at a high altitude.

A Desktop Universe

The ambitious programme of the Space Telescope Science Institute (STScI) to make available a digitised survey of the entire sky will begin at the end of this year with a survey of the southern sky, digitally compressed and stored on a set of 60 CD-ROMs (compact disk read-only memory). The northern images will be distributed in 1994 on 40 CD-ROMs.

This sky survey CD set will become one of the most important astronomical research tools available and give astronomers rapid access to images of the sky in a format readily digested by modern computers.

Two versions of the entire sky are being produced - one at a compression factor of 10, which is nearly indistinguishable from the original data, and one at a compression factor of about 100 which will fit on just ten CD-ROMs.

The higher compression is not suitable for professional research but will be an invaluable tool for educational and amateur astronomy purposes.

The original sky survey photographs were taken with wide-angle Schmidt telescopes - the Oschin Telescope on Mount Palomar (California) and the United Kingdom Schmidt Telescope at Siding Spring in New South Wales, Australia. Surveys being compressed are the southern J band survey (894 plates; epoch 1975-1984) and the northern Palomar E band survey (583 plates; epoch 1950-56).

The photographic surveys were originally digitised during an intensive eight-year effort to prepare the Guide Star Catalog (GSC) which provides the coordinates of target stars used by NASA's Hubble Space Telescope for acquiring and locking on to celestial targets.

This took five years and involved scanning 2100 photographic plates of the sky (including the 1500 deepest ones being used for the present CD project), then converting them into a huge computer data base. The digitised scans represent a huge quantity of data. Each of the 1500 plate scans is 14,000 picture elements on a side, which adds up to 600 billion bytes of data in all.

The sky survey CD-ROMs, when released, will become a powerful resource for a wide range of research: e.g. galaxy counts, supernova and variable star searches, identification of optical counterparts to sources of invisible radiation, multi-object spectroscopy and preparation of finder charts.

A distribution plan is being worked out to make the compressed sky survey sets affordable to libraries, astronomy departments, and amateurs around the world. The 100 CD-ROM set will take up only two linear feet of bookshelf space!

HST Observations

Black Hole Explanation for Active Galaxies

Observations, by the Hubble Space Telescope (HST), of the nearest Seyfert galaxy, NGC 4395 support the theory that active galaxies are fuelled by a massive black hole at the centre and rule out vigorous star formation as the alternative explanation for the mysterious power source behind quasars and extremely bright galactic nuclei.

Seyfert galaxies are galaxies with extremely bright central regions that often obscure the much dimmer stars in the surrounding galaxy. Quasars - quasi stellar radio sources - are among the most distant objects in the universe and are visible from Earth only because they are so bright. Both types of objects, collectively referred to as active galactic nuclei (AGN), give off prodigious amounts of energy, with much of the radiation in the form of high-energy x-rays and gamma rays.

Observations over the past 30 years have convinced most astronomers that the only object capable of producing such tremendous amounts of energy in a relatively small galactic core is a black hole. A competing explanation is the starburst hypothesis, which proposes that some active galaxies are bright because of vigorous star formation at the centre viz a starburst activity generating massive hot stars that evolve rapidly and explode after a mere 10 million years.

NGC 4395 was chosen to test the starburst hypothesis because the region around the nucleus is nearly devoid of stars, which might contaminate the spectra and make the findings ambiguous. The Faint Object Spectrogrpah aboard the HST was used to make a seven-hour observation but did not detect any absorption lines that could be ascribed to stars in the nucleus.

Close Encounters of a New Kind

The Hubble Space Telescope (HST) has found a new stellar population isolated deep in the core of M15, one of the densest globular star clusters. They rank among the hottest stars observed in the core of a globular cluster and the most likely explanation is that they are stars stripped of their outer envelopes of gas.

According to Guido de Marchi of the Space Telescope Science Institute (STScI), these objects represent a totally new population of very blue stars.

De Marchi and Dr Francesco Paresce (STScI and ESA) think this stripping could happen only where stars are so crowded together in the core that they can lose much of their gaseous envelopes through the gravitational pull of passing stars.

About 15 hot blue stars were found to be segregated at the very core. Their surface temperatures are above 60,000 degrees F (our Sun's surface is 11,000 degrees F). This could be caused in several ways other than stellar stripping e.g. magnetically stirred-up super massive stars, white dwarfs or planetary nebulae. However, none of these scenarios explain why the stars are so concentrated and so numerous and be only within one light year of the core of the cluster, with 90 percent of them concentrated within a four-tenth light-year radius.

It seems that the new population of blue stars was once the cores of red giants which expand to enormous sizes late in their lives due to changes in the nuclear "burning" at their cores. Red giants are so distended that they have a weak gravitational hold on their outer envelope of cool gas, so a normal, main sequence star passing within a few stellar radii can rob gas from the red giant. This stripping process can, in theory, expose a star's core. However, conditions where stars are so crammed together are unusual. Stars in our own stellar neighbourhood are about a million times farther apart than the distance between the Sun and Earth. In M15, due to the relentless pull of gravity, the stars at the core have converged so that they are at about 500 times the distance between the Earth and the Sun. If our planet were there, we would see a hundred thousand stars closer than Proxima Centauri, the closest star to the Earth.

M15 is 30,000 light-years away in the constellation of Pegasus. It appears to the naked eye as a hazy spot, 1/3rd the diameter of the full moon.

Note on Globular Clusters

Globular clusters are compact "beehive swarms" of several hundred thousand stars loosely held together under the mutual pull of gravity. They are deflected by gravity if they pass near each other. During such encounters, a smaller, less massive star steals momentum from the larger star. Because of these near-collisions, massive stars lose momentum and "fall" toward the centre of the cluster, like marbles rolling to the bottom of a funnel. In time, massive stars accumulate at the cluster's centre. Previous Hubble observations suggest that M15 probably contains powerful energy "storage batteries" in the form of double star systems, which prevent the core from imploding all the way down to a black hole. The rapid orbits of two stars about each other in tight binary systems creates a powerful reservoir of kinetic energy. A few double stars can stir up the motion of in-falling stars, causing the core to rebound, like squeezing and relaxing a rubber ball.

Earlier research found that another type of unusual blue star, blue stragglers, also dwell at the cores of some clusters. However, even these are not as hot nor as blue as the new population of blue stars in M15. Most are probably double stars that gravitationally capture each other. This stirs-up the stragglers' nuclear fuel and the star "resets its clock" to relive a bright and hot youth.

SPACE AT JPL

Discovering a Comet

BY DR WILLIAM I. McLAUGHLIN
Jet Propulsion Laboaratory, California, USA

Discovering comets and asteroids is hard work. Eleanor Helin, known to her associates as "Glo," and her team have garnered 15 comets and about 80 near-Earth asteroids from their labors over the last 20 years. Helin is a pioneer in the discovery of those asteroids which visit the vicinity of Earth, asteroids which are playing a growing role in solar-system studies. (See the June 1993 edition of this column.) Understanding the work of her PCAS team (the acronym stands for "Palomar Planet-Crossing Asteroid Survey") is best gained by examining the details of their observing practice and two examples of the chase: Jupiter-family Comet 1993 I and near-Earth asteroid 1993 MF.

Eleanor Helin, a pioneer in the discovery of near-Earth asteroids, is shown at the 46cm Schmidt telescope on Palomar Mountain. *NASA/JPL*

An observing session with the 46cm Schmidt telescope on Palomar Mountain begins with the arrival of the observing team at the mountain on the afternoon of the first observing night. Preparation of the film and a check of the telescope and support equipment is initiated immediately after arrival.

Following the afternoon preparation and a hurried dinner, the observing session begins. In winter, of course, the available period of darkness will be considerably longer than summer and so sessions on the Schmidt can last up to 12 hours.

A block of four preselected fields-of-view, each exposed for six minutes, is taken of the sky. This block initiates the observing program for the night. Most fields are photographed within a strip about the ecliptic (the plane of the Earth's orbit, which is close to coincidence with the basic plane of the solar system), where many near-Earth asteroids are found.

The Schmidt telescope is tracked at sidereal rate and manually corrected with the use of a lighted reticle in an 8-inch guide telescope.

Three, sometimes four, members of PCAS, collaborate in an observing session: one to guide the telescope, one to "run" between the telescope and the dark room, one to develop film and one to manage the program and scan the film. Their objective is to make as many optimal photos of the sky as possible.

The first light of dawn or moonrise usually ends the night's work.

Generally by noon the crew is waking up in "the Monastery" and breakfasting on, perhaps, cereal. (The Monastery is the building where the astronomers sleep and eat, and the name is inherited from a structure of like function on Mount Wilson.)

The afternoon is spent scanning films (Kodak 4415) exposed in the last observing session: the previous night and early morning hours. The films are scanned by means of a stereo microscope with each eye looking at an image of the same star field; the only difference is that these images were taken at different times (typically, 35 minutes apart). The brain merges the stellar images seen by each eye into one simple image, but its neural software, in devising a treatment for a "star" that has moved, i.e., a comet or asteroid, provides a visual presentation which facilitates detection. If the apparent motion has been slight, the moved object will appear to levitate above or sink below the plane defined by the stellar images. If the motion is sufficiently large, the brain cannot unite the two images and the separated image of the moving object becomes obvious. But scanning all of those specks is not an easy task, and concentrating on the star fields leads to eye fatigue and strain.

Films acquired on May 17, 1993 and a second set of films exposed on May 19 were scanned, and a diffuse object was seen through the stereo microscope. As is customary, the positional information was sent (by electronic mail) to Brian Marsden, Director of the Minor Planet Center (MPC) at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts. This communication initiated a flow of information to the MPC, requests for confirmatory observations at other sites, and additional observations from Palomar. I reproduced some of the interactive message traffic, sans numerical data and, for brevity, portions of the text. The designation "1993 I" denotes the same object as "Comet Helin-Lawrence" and is "I" in the series of letters (for comets) starting with "a."

Ken Lawrence, Eleanor Helin, and Jeff Alu (foreground) of the Palomar Planet-crossing Asteroid Survey (PCAS) are shown in their laboratory. *NASA/JPL*

Brian: Here is a comet suspect discovered by E. Helin and K. Lawrence on the 0.46 m for PCAS. Films taken by E. Helin, K. Lawrence, and M. Nassir. Object confirmed and measured by J. Alu. [Celestial coordinates given] It is a diffuse object with central condensation.
Glo and Ken 6/1/93

Helin has encouraged an acquaintance of some time, John Rogers, an amateur astronomer in Camarillo, California, to acquire follow-ups to confirm a comet or asteroid when observations are not forthcoming elsewhere. Hence a communique -- call for help -- was sent to him.

John: Here are two positions of this new comet. Let us know if you can observe it. Thanks.
Glo and Ken 6/2/93

Hey PCAS Gang! Congratulations on the discovery of 1993 I! It must feel good to get back in the action. Here's to more fu-

ture discoveries.

Perry Rose 6/2/93
Mt. Wilson

(Rose has been a part-time observer with PCAS and is now a solar observer at Mt. Wilson.)

Dear Glo: Your new comet was accidentally observed in Japan on May 27. It's probably of short period but we are not quite sure.

Nakano 6/3/93
Japan

(Nakano is a dynamicist and coordinator of a group of Japanese observers.)

Glo and Ken: Thanks for the information. I was able to photograph the comet field last night but again nothing obvious. The weather does not look good for tonight, but hopefully this weekend will give me another opportunity.

John E. Rogers 6/3/93

An unusual observation of 1993 I (Comet Helin-Lawrence) was made by Rob McNaught from Siding Springs, Australia. The comet was close to the full Moon, which would normally have precluded observations, but a lunar eclipse fortunately darkened the moonlit sky and allowed the object to be photographed.

Rob: We wanted to send a BIG thank you for your observation of 1993 I during the eclipse! Quite a trick. Glo is off to the ACM meeting while I'm holding the fort down. We head to Palomar on the 20th, so let me know if anything you need observations of is heading our way.

Ken 6/4/93

With a lot of observations, worldwide, of Comet Helin-Lawrence having been collected, the object's orbit was well determined, and, consequently, it joined the class of solar-system objects whose future positions can be predicted to permit further observation. It is one of the relatively rare members of the Jovian family of comets which makes a deep excursion inside Jupiter's orbit.

Comets are a bonus for PCAS, a by-product of their search for near-Earth asteroids (NEA). Helin is a pioneer in the discovery of these objects (see the January 1989 edition of this column), and in addition to her "official" interactions with the Minor Planet Center, she has led and coordinated the International NEA Survey (INAS), which represents the international extension of PCAS.

As Holmes said to Watson, "the game is afoot," and it is fitting to close with a few E-mail messages in the hunt for NEA 1993 MF. I include only two of the 20 or so in the file on this object. ("Gareth" is Gareth Williams at the MPC.)

Brian/Gareth: We have found a bright fast-moving asteroid moving prograde at approximately 1.5 deg/day. [Celestial co-ordinates given] We are at this moment retaking the field. We have not been able to identify it with any known object.

Glo and Ken 6/24/93

Glo/Ken: Congrats on the discovery of 1993 MF. Looks like a nice bright one to follow for a while. Well, I better not keep you. You must have plenty of film to scan.

Perry 6/25/93

Aerobraking Magellan

Having completed the primary mission goal of mapping the surface of Venus with high resolution, the Magellan spacecraft has been placed in a second scientifically advantageous orbit through a carefully planned set of interactions with the Venusian atmosphere. Aerobraking, like a gravity-assist maneuver, utilizes features of the environment, rather than exclusive employment of the spacecraft's propulsion subsystem, in order to modify a trajectory.

The overall plan for Magellan's orbital shaping was carried out in three stages: (1) cautiously lowering the spacecraft into the atmosphere of Venus through propulsive maneuvers, (2) waiting until friction with the atmosphere had drained sufficient energy from the orbit to collapse its dimensions to close to the desired values, and (3) using a few propulsive maneuvers to lift the newly shaped orbit above the grasp of the atmosphere. The Magellan flight team has labelled the third phase as "back to the vac."

In order to gain insight into the aerobraking process, I made an appointment with Rob Lock, Chief of Magellan's Mission Planning Team. Walking over to the Space Flight Operations Facility (SFOF), by chance I encountered the Project Manager of Magellan, Doug Griffith. We were colleagues for the Uranus leg of Voyager's mission and talked for a few minutes.

With aerobraking successfully completed, Griffith's principal concern is to obtain funding for his "lean, mean, gravity team" for the next year. As of now, no funds have been allocated to operate Magellan for Fiscal Year 1994, and the new orbit, closer to the planet, would enable high-resolution studies of the structure of the gravity field of Venus to be conducted. Relating such results to the topography of the planet, already revealed through Magellan's synthetic aperture radar, would substantively increase knowledge of geological structures and processes; one investment complements the other.

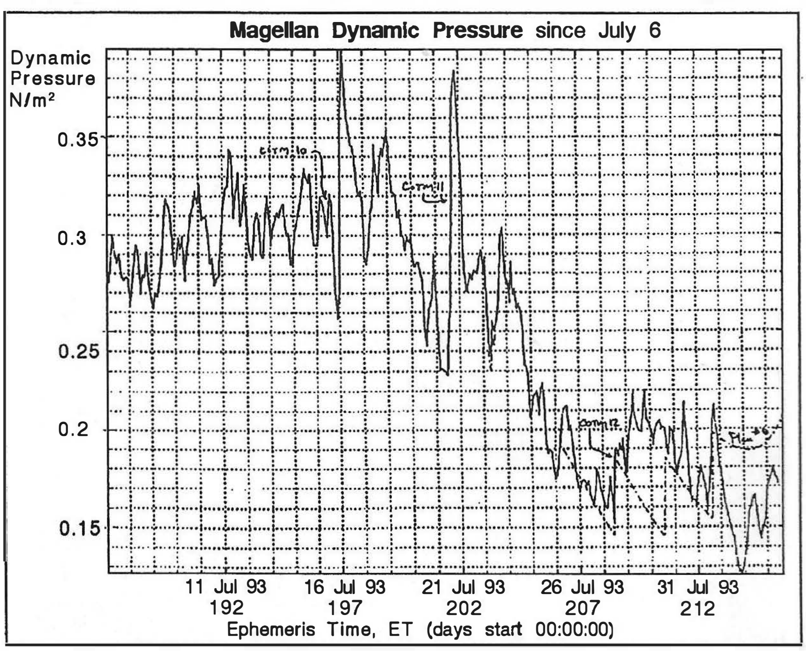
My JPL badge, strengthened with tape in its old age, was no match for the badge reader at SFOF, so Lock met me at the door. Passing through one more badged door into the Magellan area, he outlined the story of the last 70 days.

A "virtual particle," in physics, is one that exists for a short period of time, even though its existence violates the law of the conservation of energy: a circumstance made possible through a loophole in the law opened by Heisenberg's uncertainty principle. The Magellan project created, by analogy, what they called a "virtual team" to address aerobraking. The "Aerobraking Planning Group" (APG) was assembled from three standing teams: Mission Planning, Navigation, and Spacecraft. Lock was chair of the APG for its 73 days of existence.

The strategic principles under which the APG, and the entire project, carried out aerobraking were: "Neither a wimp nor a martyr be: be aggressive, be on the cutting-edge, but don't be suicidal."

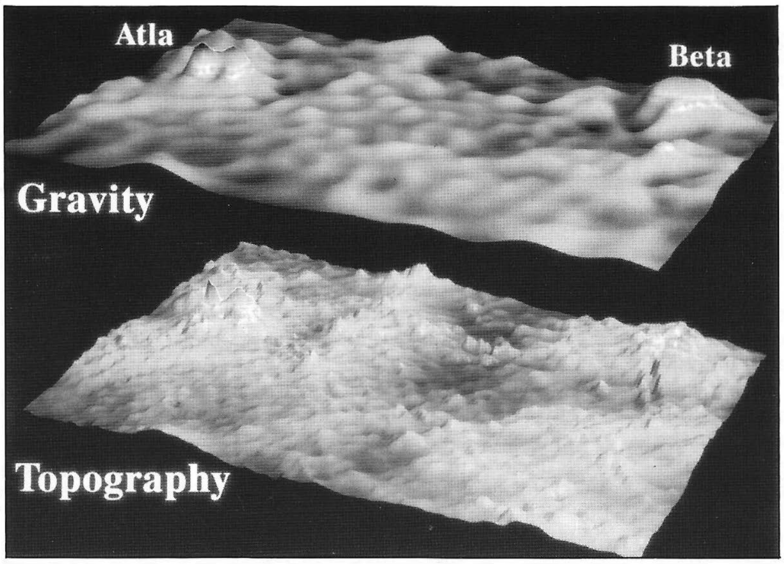
The initial orbit with which the APG would begin its work was "172km X 8460km." That is, the low point (periapsis) in the elliptical path of the spacecraft about Venus was 172km above the surface of the planet while the high point (apoapsis) was 8460km dis-

During the aerobraking process, used to alter Magellan's orbit about Venus, the spacecraft was immersed for several minutes of each orbit in the atmosphere. In order to avoid damage, the pressure had to be monitored carefully. This plot shows how the pressure fluctuated during part of July 1993. The largest pressure spike, on July 16, was labelled "the mother of all density waves" by the flight team. *NASA/JPL*



tant. The end state, after the completion of aerobraking, was a more nearly circular 197km X 540km orbit.

Moving periapsis into the substantive atmosphere of Venus (Stage 1, above) through propulsive burns, was guided by knowledge of the structure of Venus's atmosphere contained in the Venus International Reference Atmosphere, which was developed by Gerald Keating of NASA's Langley Research Center. Dipping the periapsis into the atmosphere posed two major dangers: the spacecraft's solar panels might overheat through friction with the atmosphere, causing solder joints to fail (178° C), or the high-gain antenna might be structurally damaged if its epoxy resin were heated above 205° C. The aerobraking force on the vehicle, by terrestrial standards, was quite weak: about one thousandth of the tug of gravity on an object on the Earth's surface.



Magellan's fourth eight-month cycle of Venus mapping, which began in September 1992, was dedicated to collecting gravity data. The computer-generated perspective shown here compares gravity and topography over a region 12,700 km by 8,450 km. The correspondence between the two maps is interpreted to indicate that, relative to Earth, the formation of features on Venus is more strongly linked to fluid motions in the mantle. *NASA/JPL*

Walking into the atmosphere required four propulsive burns, which left periapsis at 141 km in altitude. During Stage 2, atmospheric friction, effectively operating from 5 to 12 minutes per orbit, about the time of periapsis, removed energy from the orbit. The reduction in energy was manifested by the lowering of the altitude of apoapsis. (The energy of an elliptical orbit is measured by the distance between periapsis and apoapsis, "the major axis" of the ellipse, and decreases with decreasing major axis.)

But removing energy was not a passive process in which only nature played a hand.

The proper density of atmosphere was selected, during "walk-in": too low a density would mean that the aerobraking process would last too long, and too high a density could damage the spacecraft. Thus, a density "corridor" was sought by the walk-in and had to be maintained during the period (Stage 2) that periapsis was immersed in the atmosphere. Maintenance was accomplished by "corridor orbital trim maneuvers." Atmospheric density varied during aerobraking because of variations in the atmosphere itself and fluctuations in the altitude of periapsis as a consequence of complexities in the gravity field of Venus.

On July 16, 1993, a large density wave in the atmosphere was so impressive in magnitude that it was named "the mother of all waves." Atmospheric density was estimated by means of solar-panel temperature measurements, telemetered to Earth, and through navigational tracking data.

The spacecraft was oriented during aerobraking with the front side of the 3.7m high-gain antenna pointed away from the relative wind and the solar panels at 90 degrees to the wind direction, making the spacecraft somewhat like a badminton shuttlecock. The aerodynamic properties of this configuration yielded a high degree of drag and stability.

Lock said that one of the most difficult problems during aerobraking arose from timing variations in the spacecraft's traverse of its path. The spacecraft, like most interplanetary vehicles, carries an onboard computer program -- "a sequence" – which supplies instructions on how to carry out day-to-day activities: initiate a motor burn, point the antenna to Earth in order to transmit data, etc. Each command in the sequence has a time tag associated with it, and consulting the onboard clock, the spacecraft then knows when to execute the command.

The effects of atmospheric drag are difficult to predict in normal times, but under the regime of aerobraking the difficulties are multiplied. Hence, there was a noticeable variance in the location of the spacecraft in its orbit as a function of time; errors in predicting the time of arrival at periapsis built up rapidly and could amount to two minutes, sometimes in less than a day. And two minutes error was about the maximum that could be tolerated without having the spacecraft "doing the right thing at the wrong time."

The solution to the timing problem was to initiate critical events by command from the ground, which had more up-to-date trajectory information than that encoded into time tags of the commands in the onboard sequence. The information for determining the time of periapsis passage came from two independent sources: (1) telemetered data from the spacecraft's attitude-control and thermal subsystems, and (2) navigational data. Usually, the former information was available in a couple of hours and the latter in about half a day.

The importance of demonstrating that aerobraking works may have a significant impact on the design of some future missions. Consider the statistics. Normally, about 900kg of propellant would have been required to accomplish Magellan's orbit change while the spacecraft used only 38kg in combination with the ministrations of Venus's atmosphere. (Magellan only had 94kg remaining, from the stock of 129kg at launch.)

Magellan, mapping 98% of the surface of Venus with radar, in four 243-day cycles of orbital operations, has been an enormous success and another jewel in NASA's scientific crown. Demonstration of the feasibility of aerobraking has added to the sparkle of the scientific achievements, and we may see, funds permitting, high-resolution gravity studies incorporated as the final accomplishment of the mission.

Strategy

Almost everyone, from time to time, employs the word "strategy" to describe a course of behavior in some situation. It could be strategy on a grand scale, a college student planning the future, or strategy in the small, deciding the best use of a weekend. This past summer, I became involved in strategic planning activities at JPL and working in a similar vein with colleagues at NASA Headquarters.

In performing these activities, and, even more so, in consulting literature on the subject, I was struck with the diversity of interpretations which people apply to the concept denoted by "strategy." A few forays – thinking and reading – on my part failed to arrive at a satisfactory definition for this popular term, and I will try again here, followed by some personal opinions on a strategy for space.

While "strategy" as applied to many human activities may be difficult to disentangle from "tactics," "long-range planning," etc., there are areas in which the term may thought to be employed with some confidence. The game of chess is one such arena; the practice of war is another.

Wilhelm Steinitz (1836-1900) was chess champion of the world, and, in one version of the history of the game, was the first player to apply, in consistent fashion, and teach, basic strategic principles that are still relevant: control of the central region of the board, early mobility for the pieces, etc. Although many good players were aware of these practices, much of chess was concerned only with the fire-

works of tactical play. Steinitz did not drive brilliance from chess, but he did place constraints on its appearance.

The chess grandmaster Richard Reti (1889-1929) and others of the "hypermodern school" formulated a somewhat different approach to chess. For example, they advocated probing the central region of the chessboard from long range rather than the Steinitzian preference for direct occupation of that region by the foot soldiers of chess: pawns.

Thus, the strategic principle of controlling the center was implemented by two different tactical schemes, and modern practice has accommodated both.

Historians have persisted in their search for the cause or causes for the decline and fall of the Roman Empire. Economic, social, and military theories have been advanced. Arther Ferrill has argued in *The Fall of the Roman Empire* (Thomas and Hudson Ltd., London, 1986) that a strategic error brought the huge empire down. Prior to the time of Constantine the Great (c. 274-337), Roman legions fortified the boundaries of the Empire in a perimeter-type defense: Hadrian's Wall in England exemplifies the method. Ferrill claims that this strategy was well suited to the specific tactics of the fighting legions. Constantine diluted the border defenses and strengthened the Empire's central reserve of troops; a strategic change which, according to Ferrill, fatally weakened the Roman army in its struggle against the barbarian hordes which eventually overran The Western Empire.

However, when one considers a business firm or a government agency, the meaning of "strategy" is more difficult to discern. This observation appears to be widely accepted. In *A Logic for Strategy* (Ballinger Publishing, 1988), Daniel Gilbert and his co-authors undertake the dual task of defining the essence of the concept of strategy and promoting its use in business management. I found the work interesting but not definitive.

Gilbert, et al., point out that any conception of business strategy needs to be accompanied by a "theory of the firm," i.e., a model of how business functions. This observation may help to explain why chess and war are strategically malleable while businesses and government agencies must work harder to develop strategies. War resembles chess in that both are contests (one hears of "war games"), and the imagination wraps rather easily around a contest-based entity. "Theories of the firm," and the like, are considerably more abstract than the ideas embodied in a contest. Of course, von Neumann and Morgenstern's epic *Theory of Games and Economic Behavior* (1944) injects game-theoretic concepts into economics, but the work does not provide a primal or intuitive basis for strategy.

Perhaps I have lowered expectations to the point where I can suggest some principles for the formulation of a strategy and propose a few applications to space. The principles and ideas are my own and, in general, span a longer period of time than that usually covered in the planning processes of space agencies.

The root principle of any strategy, space or otherwise, is the realization that it is important to step back from the daily pace of frenetic activity and think about what one is doing. While, intellectually, this is not a deep comment, the number of people or organizations that can levitate themselves above the time stream long enough for introspection is small.

The purpose of such reflective thought is to decide how to create conditions that will enable the values and goals of the strategist to flourish. For chess: checkmate; for war: victory; for business: profits; for space: utilization. (Aren't we, after all, enthusiasts about the cosmos?)

What distinguishes strategy from philosophical musing is that the former must include a plan for action. That is, after reflection one descends back into the "real world." In strategies for space, the plan is often presented in the form of a set of proposed missions. However, I submit that a mere list of missions, without a thoughtful basis, is sterile.

For the remainder of my characterization of strategy, I will list attributes of the concept. While a list of attributes is not as satisfying as a crisp definition with a few declarative sentences, the method of attributes has intellectual respectability. Some philosophers, C. I. Lewis (1883-1964) is one (see his classic *Mind and the World-Order*), think that an object is nothing more than the sum of its properties. More colloquially, if it looks like an elephant and sounds like an elephant....

The attributes that seem, to me, of importance are: a vision, gravity, flexibility, inclusion of tactical precepts, and pictures of possible worlds that could result from the strategy.

"A vision" is a simple expression of the integrating ideas from which the strategy springs. President Kennedy's 1961 call to place a man on the Moon by the end of the decade and return him safely constituted a very effective vision.

"Gravity" does not refer to the central element in the physical theories of Newton or Einstein; it just means that strategy treats only matters of major significance to the enterprise at hand.

"Flexibility" might seem unnecessary to mention, but it is closely allied to the raison d'etre of the idea of strategy itself: the need to stand back and reconsider the situation when conditions change. Carried to excess, flexibility degenerates into vacillation.

"Inclusion of tactical precepts" means that a strategy can reflect not only on ends but also on means. In this category I would place such methods as "systems analysis" and "total quality management" (TQM).

"Pictures of possible worlds" is another way to state that a strategy should, as noted previously, have an end in view, a plan, a set of objectives. Reference to the plurality of possible worlds acknowledges the role of flexibility.

I suggest that a strategy for space might be organized around two goals:

1. Complete our knowledge of astronomy through space (and ground-based) observations. By "astronomy" I mean to admit solar-system studies, including the Earth as a planet, along with astrophysics.
2. Initiate human occupation of affordable niches in space, niches that have a diversity of possible payoffs on investment.

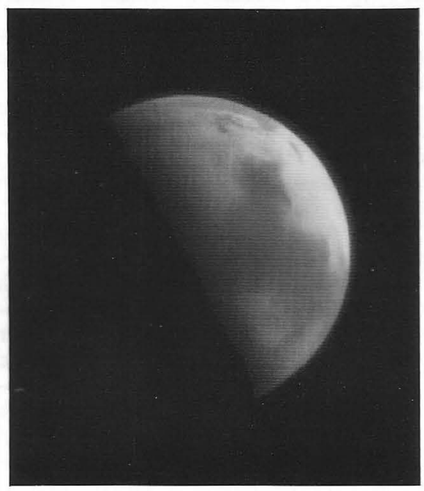
It may seem surprising to use "complete" with respect to Goal 1, but Martin Harwit (*Nature*, volume 320, pp. 724-726, 24 April 1986) contends that the number of major astrophysical discoveries that have *ever* been made is modest, and we have already achieved a nontrivial fraction thereof.

The advantages of space for astrophysical investigations include not only the removal of filtering and fuzzing due to the atmosphere but also the room to build large interferometers and mirrors to achieve enormous gains in resolution and sensitivity. One can also conduct gravitational-wave astrophysical investigations away from terrestrial sources of gravitational noise.

Completeness with regard to the solar-system component of astronomy would proceed, analogously to the substantive completion of our geographic knowledge of Earth, through voyages of exploration.

"Diversity" in Goal 2 is included in recognition that we do not know the ultimate payoff in space for human exploration and, hence, must maintain options. My hunch is that the set of asteroids, particularly the near-Earth swarm (see the June 1993 edition of this column), may compete with the Moon, in the near-term, as a candidate for an affordable, diverse niche.

The plan for implementing these strategic goals and a strategy for the remainder of eternity are left as exercises for the reader.



This photograph of Mars was taken at 8:52 p.m., Pacific Daylight Time, on July 26, 1993 by the high-resolution, narrow-angle telescope of the Mars Observer camera. At that time the spacecraft was 5.8 million kilometers from Mars and 28 days from its encounter with the planet. Resolution is approximately 21.5 km per picture element. Communication with the spacecraft was lost on August 21, 1993 prior to the planned insertion into orbit about Mars.

NASA/JPL

SOCIETY ANNOUNCEMENTS

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.

It may occasionally happen that, for reasons outside its control, the Society has to change the date or topic of a meeting. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always re-check the scheduled meetings in the latest issue.

6 October 1993 — 7 pm - 8.30 pm

Microsatellites on Micro-budgets

Prof. M. N. Sweeting

The prohibitively high cost of space projects has effectively restricted first-hand access to space to a handful of nations and international agencies. Spacecraft have grown ever larger and more complex and are also taking longer time-scales from concept to orbital operation. Advances in VLSI microelectronics have catalysed a new species of small, low-cost yet sophisticated and highly capable 'microsatellites' - complementing, and sometimes providing an alternative to, high-cost traditional satellites.

The lecture describes the University of Surrey UoSAT microsatellite programme which reviews the key technologies, management techniques and potential applications of small satellites.

SYMPOSIA & CONFERENCES

15 - 17 October 1993

SPACE '93

This two-day meeting commemorates the Society's Diamond Jubilee, 1933 - 1993. Please send to BIS HQ for details.

16 - 22 October 1993

44th International Astronautical Congress

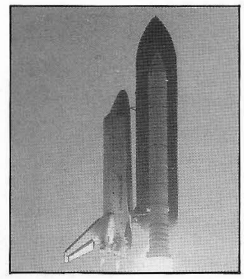
The 44th International Astronautical Congress will be held in Graz, Austria, from October 16 - 22, 1993. Details of the Programme, Registration Forms, etc. are available from BIS HQ.

LIBRARY

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. The Library will also be open on Saturdays between 10.00 am and 1.30 pm on the following dates:

23 October
20 November
18 December

Membership cards must be produced.



Space Shuttle Competition Winners

Lucky readers who shortly receive a copy of the 'STS-49 Mission Highlights' video are:

P. Callan	UK
W.P. Holwerda	The Netherlands
N. Innes	UK
S. Ferier	Belgium
A. Whitlam	UK
E. Wolff	Germany

The 'Keyword' to be found was GLIDE.

Bye-Law Revision

In response to representations that it has received, the Council has approved new wording for Bye Law 30(2) as follows:

All other business shall be deemed Special Business. No Special Business on a members' requisition shall be transacted unless notice is given to the Society by the holders of not less than one-twentieth of the total Corporate Membership Voting Rights, not less than six weeks before the date determined as that of the Annual General Meeting.

Journal of the British Interplanetary Society

The following complete volumes of ***Journal of the British Interplanetary Society (JBIS)*** are available from the Society in limited numbers.

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1950	9 *	6	24	1973	26	12	30
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1952	11 *	6	24	1975	28	11	28
1953	12 *	6	24	1976	29	11	28
1954	13 *	6	24	1978	31	12	30
1955	14 *	6	24	1979	32	12	30
1956	15 *	6	24	1980	33	12	30
1957/8	16 *	10	34	1986	39	12	30
1959/60	17 *	12	34	1987	40	12	30
1961/2	18 *	12	34	1988	41	12	30
1963/4	19	12	30	1990	43	12	30
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The October 1993 issue of the Journal of the British Interplanetary Society is now available and contains the following papers:

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Obscure Unmanned Soviet Satellite Missions

•

Biosputniks: The Use by the Soviet Union and Russia of Dogs, Monkeys and Other Animals in the Exploration of Space 1949-93

•

An Introduction to the USSR Glonass Navigation Satellites

•

Soviet Geosynchronous Orbit Satellite Activity October 1991 - May 1992

•

The Mystery of Zond 2

•

Civilians in the Cosmonaut Team

Copies of JBIS, priced at £15.00 (US$27.00) to non-members, £5.00 (US$9.00) to members, post included, can be obtained from the address below. Back issues are also available.

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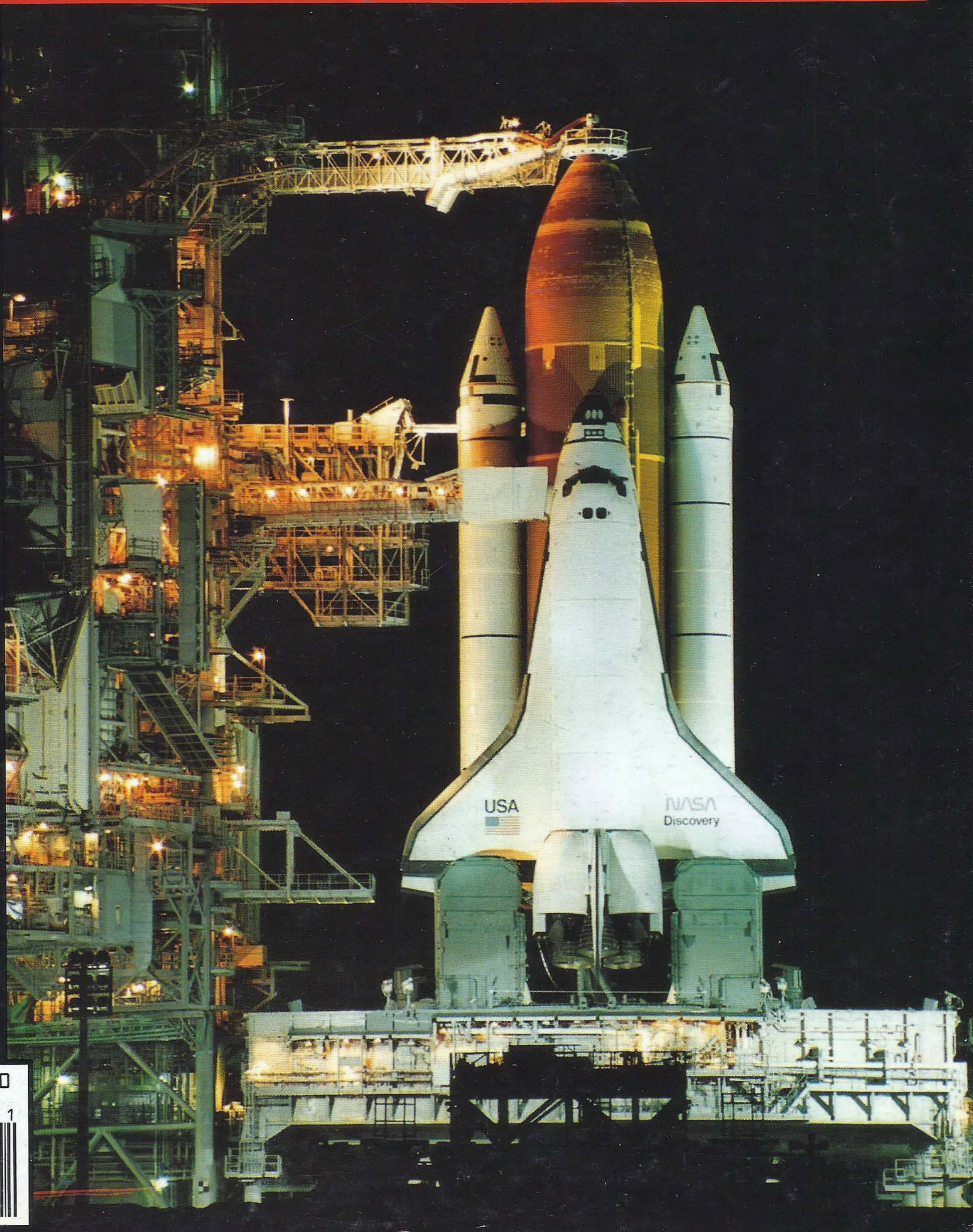
The International Magazine of Space and Astronautics



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Russia's Programme

Delta Clipper Tests

Shuttle Launch STS-51

Ariane 5 'Speltra'

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Spaceflight

The International Magazine of Space and Astronautics

Published By The British Interplanetary Society

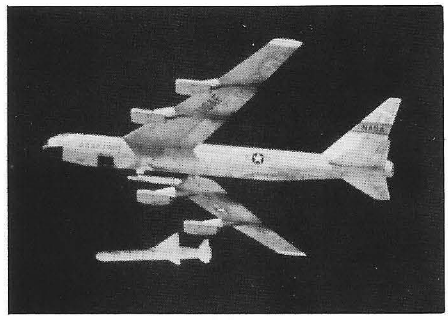
Vol. 35 No. 11 **NOVEMBER 1993**

Front Cover: Discovery on the launch pad prior to propellant loading on the evening before its launch at 7:45 am EDT on 12 September 1993 on mission STS-51. A launch report appears on p.373. *Photo by Steve Nichols*

Air-Launched Boosters

DAVID I. WADE
Berkshire, UK

Air-Launched Boosters



In April of this year the fourth mission of the Pegasus air-launched booster successfully placed a small X-ray observatory satellite in orbit. The concept of launching a rocket from an aircraft is not new, but only now with the surge in small satellite activity and the availability of large capability planes, such as the Antonov 225, is the idea truly feasible.

Since the first flight of Pegasus in April 1989, there has been a flurry of proposals made for air-launched boosters. With further flights imminent, *David I. Wade* **takes a look at what makes the concept so attractive.**

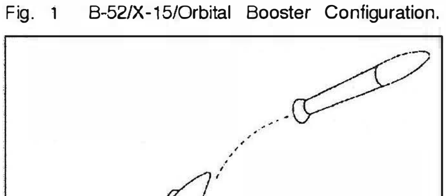
Historical Overview

The development of spaceplanes dates from the early 1920's and is chronicled in the March 1993 ***Spaceflight*** article 'Spaceplanes - Back to the Future' [1].

During the late 1950's and early 1960's a great amount of research into high speed flight was underway and led to the development of a number of the series of X-planes. Of the X-planes, one of the most successful was the X-15, making a total of 199 flights and reaching speeds and altitudes of 7297 km/h (4534 mph) and 107960 m (67.1 miles) [2]. Launched from under the wing of a B-52 carrier aircraft the X-15 itself could not reach orbit, but it was suggested that the X-15 might carry a further stage which could be released at the X-15's peak altitude and under its own power go on to achieve orbit, figure 1. Although this study gained some interest, the use of two manned stages was of concern. The small payload capability possible - at a time when one of the main drivers for launcher development was for use as a intercontinental ballistic missile (ICBM) - lead to the abandonment of the concept.

Following this study, in the 1970's work concerning a derivative of shuttle technology was considered. Whereas the shuttle had used a Boeing 747 for glide and approach tests, an unmanned expendable derivative was suggested that would be launched from the 747 to begin its ascent to orbit (similar to the Commonwealth of Independent States (CIS) MAKS study [3]). Again, although this study provided some interest, at the time NASA was winding down its expendable launcher fleet to place emphasis on the shuttle, and the idea never got off the drawing board. Later, when the worth of expendable rockets was once again realised the concept re-emerged as the ground-launched Shuttle-C, figure 2.

Fig. 1 B-52/X-15/Orbital Booster Configuration.



Left: The Pegasus air-launched space booster in lifting ascent to orbit. *OSC*

Of interest to this article is the Strategic Defence Initiative (SDI), or more affectionately known as the 'Star Wars' programme which led to the development of anti-satellite (Asat) missiles. The first launch of the US Asat missiles, from an F-15 'Eagle' fighter aircraft, occurred in September 1986 and destroyed an obsolete USAF P78-1 satellite. It is believed that the Soviet Union, at the time, had similar technology, although details were more scarce. The Asat missile was not able to attain orbit itself but could reach an altitude in excess of 300 km.

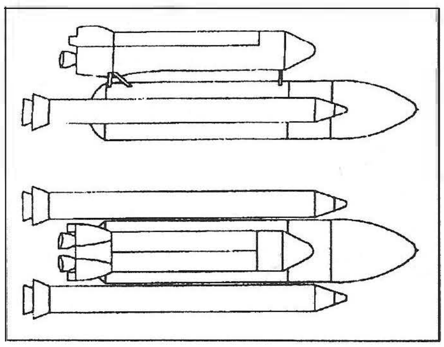


Fig. 2 The Shuttle-C Launch Vehicle.

Recent years have seen a number of studies of single-stage and two-stage to orbit (SSTO and TSTO respectively) spaceplanes. Whilst the development of such vehicles is far removed from air-launched boosters such as Pegasus, figure 3, the TSTO concepts still benefit from the same advantages of being launched from an air-borne platform. TSTO concepts were considered for the shuttle, before budgetary restraints lead to a design compromise and the present configuration adopted. Suggestions for TSTO vehicles include Max Faget's TSTO Shuttle and are described in more detail in the March 1993 ***Spaceflight*** article [1].

Whilst not all spaceplanes can be considered as air-launched, some of the recent suggestions for an intermediate step between conventional rockets and reusable SSTO vehicles, have relied on the advantages gained from an air-launch to develop a feasible concept. Launch vehicles such as Sänger and Interim Hotol (which fit this description) will be discussed later.

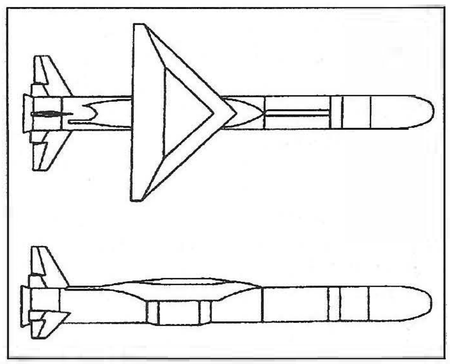


Fig. 3 The Pegasus Launch Vehilce.

The Benefits of Air-Launch

The advantages of launching a booster from a carrier aircraft are many and will be detailed below.

Conventional rocket ascent trajectories climb almost vertically through the denser parts of the atmosphere before a gentle canting over allows the vehicle to accelerate to orbital velocity, as shown for Ariane in figure 4.

Flight within the dense regions of the atmosphere causes many inefficiencies for rocket propelled devices. The use of on-board propellants leads to large volume tanks, which in turn relates to high drag losses. As the atmosphere thins the effect of drag becomes less important, however the mass of propellant required to overcome drag during the early stages of ascent is a significant proportion of the total propellant load.

By beginning the launch vehicle's ascent at typically 12000 m (40000 ft) altitude, atmospheric density is approximately one quarter of that at sea level. The drastically reduced drag losses give air-launched vehicles a significantly higher payload fraction (payload mass as a fraction of launch mass) over their ground launched counterparts. For example, Pegasus has a payload fraction almost twice that of a ground launched vehicle of similar size [4].

Other advantages are offered by an air-launch. Firstly, the carrier aircraft imparts kinetic and potential energy to the vehicle prior to ignition. Whilst this is only a small fraction of that required it benefits the overall launch to pro-

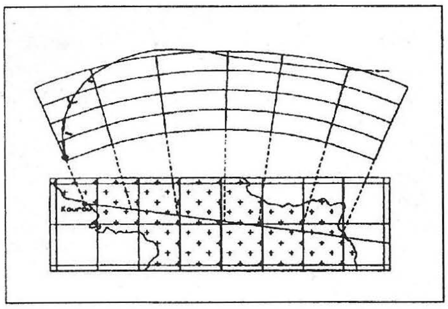


Fig. 4 Ariane 4 Ascent Trajectory.

duce the higher payload fraction attained.

Secondly, at ignition, the lower ambient pressure allows a more efficient nozzle design to be made. Nozzle designs operate most efficiently at a fixed ambient pressure, however the range of altitudes (and hence pressures) experienced by a typical rocket's first stage makes the design a compromise. For an air-launched vehicle the smaller range of pressures encountered means the nozzle design need not be as compromised and hence can operate more efficiently.

The third advantage of an air-launch also benefits from the lower ambient pressure at altitude. As the launcher accelerates it passes through a point at which the maximum dynamic pressure occurs. As the ambient pressure is reduced then the loads placed on the rocket are lessened and the structural design can be simplified, resulting in a lower mass for the rocket's structure. If a winged configuration is used for an air-launched booster, such as Pegasus, even further advantages appear. The ascent trajectory of Pegasus uses lift developed by the wing to aid its climb through the atmosphere. Taking Pegasus as an example, its steady climb at an angle of about 40° dictates that a significant proportion of propellant is saved on the first stage, as the wing lift raises the vehicle's altitude.

Further, the air-launch of any booster offers three more benefits not available to ground launched systems. Firstly, a mobile launch platform, such as the carrier aircraft, allows a wide range of orbital inclinations to be entered without wasteful 'dog-leg' manoeuvres. Ground launched vehicles are usually restricted to only a couple of inclinations, depending on the launch site latitude and the proximity of inhabited areas.

Following launch, launch pads usually require an amount of refurbishment to be performed, before further launches can occur, to repair the blast damage. The second advantage, is that for an air-launched system, as no launch pad exists, then the rate at which launches can occur is only limited by the availability of the carrier aircraft and production rate of the booster. This allows a launch rate that is presently unprecedented.

The final advantage for an air-launch system is simply that at release of the booster from the aircraft, the altitude means that the worst elements of the weather are avoided, hence launch is less likely to be hampered by poor weather conditions.

Present Air-Launch Boosters

At present only one air-launched booster is operational, that is Pegasus. First flown in April 1989, a further three missions have been successfully completed, placing a total of 12 satellites in low Earth orbits. The standard Pegasus launcher has a payload capability of approximately 350 kg to an equatorial low earth orbit, although this can be enhanced by the use of a hydrazine upper stage, named HAPS. Pegasus has a launch mass of 18500 kilograms and a length of almost 16 metres. The vehicle uses a three stage solid propellant design and composite material structure.

Later this year, a derivative of Pegasus, called Pegasus XL will be launched for the first time. The limiting payload capability of the original Pegasus has been enhanced by around 30%. This payload increase has been achieved by 'stretching' the first and second stages of Pegasus to allow the loading of extra propellant by 24% and 30% respectively, see figure 5 [5]. Operating both Pegasus and Pegasus XL together, Orbital Sciences Corporation hope to attract more of the small satellite launch market, by covering a wider range of payload masses.

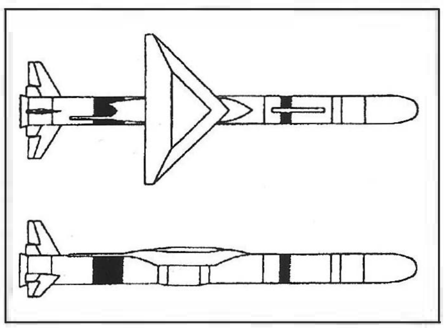


Fig. 5 The Pegasus XL Launch Vehicle.

Following the initial launch of Pegasus a number of proposals were made for air-launched boosters worldwide. Although none have flown to date a brief overview will be provided here, with the more adventurous ones being discussed under future developments. We consider these proposals on a country by country basis, firstly German.

With a low Earth orbit and payload capability of around 400 kg, the German company OHB have proposed an air-launched vehicle called Diana. The initial study suggested the use of Concorde as the carrier aircraft, to gain extra kinetic energy at launch due to the higher aircraft speed at release [6].

Similar in size and capability to Diana, the CIS suggested a vehicle named Burlak. Studied by the Raduga Design Bureau, the vehicle was again to be launched supersonically, this time from the back of a Tupolev 160 aircraft. Also under study by the CIS (Yuzhnoye Design Office) was a much larger air-launched vehicle, using a configuration of 3 or 4 stage solid propellant engines to deliver between 150 kg and 800 kg to low Earth orbit. The Space Clipper, figure 6 [7], (not to be confused with the US Delta Clipper proposal) would be derived from the SS-24 ICBM and would be launched from an Antonov 124 aircraft.

The Space Clipper differs from the other designs in not utilising a winged first stage. Although the booster would benefit from lower drag losses due to release at altitude, the advantage of wing lift would not be gained.

The final proposal would again be of the size of Pegasus, Diana and Burlak, and able to place a payload of around 500 kg into LEO. The suggestion, from Aerospatiale of France, would use two solid propellant stages, topped by a liquid propelled third stage and would be launched from an Airbus. As with Pegasus a winged configuration would be used for this design.

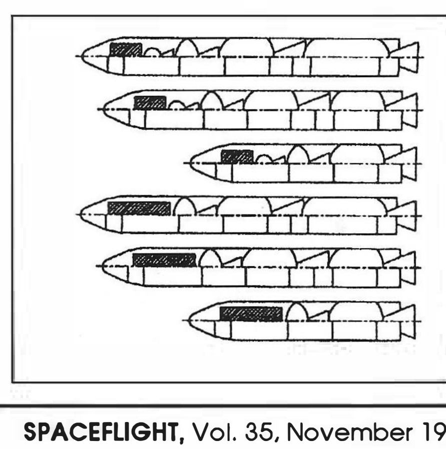
The Future of Air-Launched Vehicles

With the advent of air-launch vehicles, and the great deal of interest generated, what of the future of their development?

Initially, air-launched vehicles flying from non-specially designed carrier aircraft were destined to be of small launch capability, however with planes such as the Antonov 225 this restriction fades.

Through lack of funding for the initial Hotol aero-spaceplace concept, an interim version has been suggested which would use standard rocket propulsion rather than the air-breathing engines originally conceived. To be able to reach orbit Interim Hotol, figure 7, would need to be air-launched, and the carrier aircraft

Fig. 6 The CIS Space Clipper Launch Vehicle.



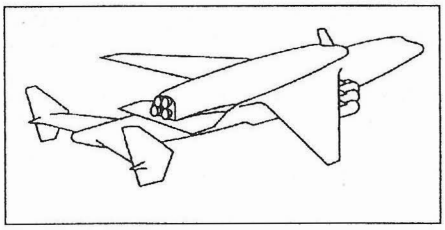


Fig. 7 Interim Hotol.

suggested would be the Antonov 225. Able to transport about 7000 kilograms to LEO the craft would then reenter and glide back to earth to be used again. Studies are now underway to analyze the feasibility of the Interim Hotol concept and the initial results seem promising.

Of greater complexity, the German Sänger TSTO aero-spaceplane, figure 8, could deliver a payload of the order of 3000 kg to LEO. Releasing a small rocket stage from the back of a specially designed supersonic first stage, Sanger's development would be costly but would also benefit future supersonic transport aircraft development.

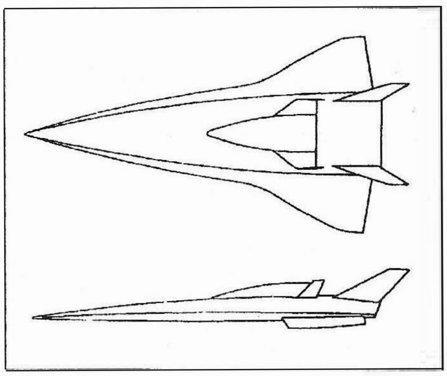


Fig. 8 Sänger TSTO Spaceplane.

Other similar TSTO concepts are still under study around the world, considering the use of scramjet and liquid air-cycle engines (LACE) to provide sufficient thrust.

At the opposite end of the complexity and payload scale, studies are also presently being conducted to another addition to what will become the family of Pegasus derived vehicles. The proposal suggests the use of low technology air-breathing engines, such as turbo-jets [8] or ramjets [9], to carry the vehicle from its release altitude of 12000 m to a height of around 25000 m before the first rocket stage is ignited. Preliminary analysis, of the Pegasus XLT concept, shows a worthwhile increase in payload capability and the idea is presently under serious consideration.

Conclusions

The advantages of launching from an aircraft are numerous and result in a significantly increased performance. The need for a small launch vehicle has been partially fulfilled by the novel Pegasus design. The launcher community has had to be patient for the first such design to be developed. With larger aircraft available, more capable air-launch boosters can now be contemplated.

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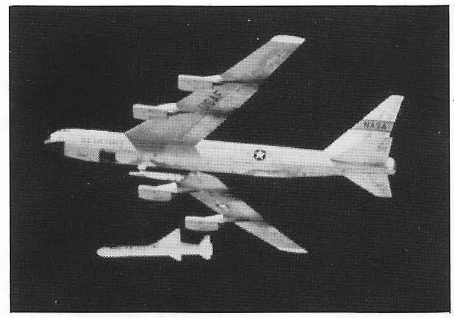

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ESA Studies Reusable Winged Launchers

The atmosphere contributes to the lifting of a winged launcher during ascent, and it also enables the vehicle to glide back to Earth. Reutilisation is therefore an important feature of such launchers. Secondly it contributes to propulsion by providing mass to be ejected at high velocity: this is air-breathing propulsion.

Advantage of Wings

In the case of a propulsion failure during ascent, a vehicle with aerodynamic lift can dump its propellants before gliding safely back to the ground. Using wings for ascent also allows the vehicle to be flown to a pre-defined orbital plane, and on reentry wings give some flexibility in the selection of the landing point. Finally the time spent in the atmosphere can be used to collect and store some of the air for later use during the rocket-driven, final injection into orbit.

Technical Complexities

Unfortunately, the advantages of an air-breathing launcher are bought at the expense of tremendous complications and technological difficulty, which puts the air-breathing launcher beyond the level of today's technology. In fact, an air-breathing launcher is by orders of magnitude more complex than any rocket launcher in service today. The complexity of the air-breathing launcher is due to the need to achieve high speeds within the atmosphere, while the strategy of the rocket launcher is to rapidly leave the atmosphere to build up speed at much higher altitudes. The high speeds to be achieved within the atmosphere lead to structural aerodynamic heating up to temperatures exceeding even those encountered at reentry. Such high heat loads have consequences on the materials with which these winged launchers will be built. Ceramic materials are generally being considered.

Our present designs centre on cooled structures, but even these have to operate at temperatures in excess of 1000 K. Using air for propulsion up to hypersonic speeds is also a difficult challenge. We know that the air has to react completely with the fuel within a few milliseconds and motors with such capabilities do not yet exist. They still have to be researched, developed and demonstrated. In addition, such air-breathing propulsion systems are very complex, have to cope with a continuously changing flight regime and have to be protected during re-entry. They often combine rocket and air-breathing propulsion elements and are therefore sometimes, termed 'combined engines'.

Industrial Involvement

Industry has studied a few possible combinations for ESA. These engines are however heavier than rocket engines while delivering less thrust for a given mass, so that some of the propellant mass saving is lost in heavy, complex and expensive hardware. It is essentially because of the US effort on the NASP that there has been a worldwide revival of interest in winged launchers. Another trigger has been provided by the work in the UK on HOTOL, followed later on in Germany by the start of the Sänger II programme.

ESA Policy

These activities have led ESA to begin the investigation of winged launchers in the context of the so-called 'Winged Launcher Configuration Studies'. It should be noted that these studies do not reflect a commitment by ESA to this type of architecture. They are simply part of a general assessment study to decide whether or not reusable launchers, in their various possible designs, are the way to go to facilitate access to space.

An edited version of the article 'ESA Studies Future Launchers; The Winged Launcher Configuration Studies' by H. Pfeffer in Reaching for the Skies, No.8, June 1993, ESA Publication Division.

A Country in Crisis . . . Space Budget Cuts . . . But Still With Great

Russian Cosmonautics in Difficult

"We have to speak about this despite the fact that about 140 Russian civilian satellites are continuing to operate in orbit".

More than twenty Russian satellites provide global communication links. Thirteen form a worldwide system which helps sea-going ships and aircraft to establish their position and the rest engage in photography and exploration of the Earth, meteorological observations, geodesic measurements, and the study of stars and galaxies. Though the number of launches has sharply diminished, 25 were conducted in 1992 alone.

Manned Spaceflight

The Russian crisis has not prevented the continuation of the many-year-long operation of the unique Mir orbital station. An international crew, which included French cosmonaut Jean-Pierre Haignere, was recently stationed in Mir. The Americans, who cannot make a final decision on what the orbital station Freedom should be and how to save the tax-payers' money at the same time, are interested in details of the nearly-100-tonne Russian orbiting station and its operations. There are plans to expand it by joining on two more modules.

Future German cosmonauts are preparing to wear spacesuits now being devised for them at the Russian scientific and industrial association "Zvezda", which made spacesuits for Yuri Gagarin and continues to do so for all cosmonauts since.

The National Space Research Centre of France hopes, with Russia's help, to amass the knowledge and experience necessary for ensuring effective preparation of its own space pilots. Tests of Hermes spaceplane models have long been proceeding at the same experimental installations where models of Soyuz manned spacecraft and the Buran winged space shuttle were tested.

Buran, which has made only one orbit around the Earth, is biding its time in a huge hangar until a decision concerning its destiny is made. Funds which have been allocated from the budget are only enough to maintain the space shuttle on land. And this land (with all the launching equipment, assembly and test buildings, a ramified network of roads and service lines, and highly sophisticated power facilities) is now the subject of a dispute between Russia, which built the Baikonur cosmodrome, and Kazakhstan, which owns the territory. While the leaders of the two former republics of the USSR are tackling existing problems, the cosmodrome and the city of Leninsk which serves it have been gradually falling into decay.

Russia also has the Plesetsk cosmodrome in the North, near Arkhangelsk, but not all rockets by a long way can be launched from its launching pads. The main problem is that it is not equipped with pads for launching Proton, which carries into orbit large communication and navigation satellites, orbital stations of the Salyut and Mir types, and interplanetary robots designed for the Moon, Venus and Mars.

Mars Exploration

A new international expedition is to set out to fly to the Red Planet next year. It will be an automatic interplanetary spacecraft fitted out with a large set of sophisticated scientific instruments. It will carry two small meteorological stations capable of transmitting information on the weather on Mars from its surface, and two 40-kilogramme probes each of length 150 cm and width 12 cm, designed to burrow themselves into Martian rock and study its composition and mechanical properties. Scientific data will be transmitted from the landing modules to Earth via the main unit of the space vehicle, which will remain in near-Mars orbit. It will also be observing the planet from orbit.

There are plans to deliver a small planet-rover and a large balloon to Mars by means of a new Russian interplanetary station in 1996. After the balloon becomes filled with the helium that is carried with it, it will fly over the planet's surface, carrying a payload of scientific equipment. In daytime the balloon will ascend to a height of 2 to 4 km and at night, having cooled down and lost its buoyancy, will descend to the surface of Mars.

Using the balloon, scientists hope to investigate below the Martian surface for the first time ever. For this purpose, specialists of the Moscow Technical University of Communications and Information Science and of the Space Research Institute of the Russian Academy of Sciences are devising a pneumatic annular antenna with a diameter of 20 m which could be suspended from the balloon. It is intended to use the device to locate water. Water may exist on Mars in a liquid form, hidden under ice at a depth of 80-100 metres.

As well as the difficulties with the cosmodromes there is the plight of space industry enterprises which are subject to conversion, the fact that more than 40,000 highly-qualified specialists have left them, the breakdown in the delivery of materials, parts and components and limited financing. Despite these difficulties the Russian Space Agency has drafted a long-term programme for the period up to 2000 and is doing its utmost to fulfil it.

The programme provides for new remote flights to Mars and its satellite Phobos with the aim of bringing samples of rock of both celestial bodies back to Earth. The missions are to be carried out within the framework of international cooperation with the participation of scientists and firms of more than twenty European and American states.

It is possible that, prior to all this, an unusual envoy of the Earth, a craft equipped with a solar sail and driven by solar wind will leave for Mars. The leading space industry organisations of Russia have now formed a consortium headed by the well-known scientific and production association Energiya and are working on this project at the present time. The craft is a huge construction 200 metres in diameter but with a mass of just 500 kg. It can rotate in orbit and consists of two thin-film mirror disks which rotate inside each other. There are plans to use the huge sailboat in the Novy Svet (New World) experiment - the illumination of Earth from space with reflected sunlight.

Space Applications

Such exotic projects are not the main part of the Agency's programme which aims, above all, at satisfying the most pressing needs of Russia's population, such as providing a high-quality communications system. At the present time, this is based on the use of the Gorizont and Ekran satellites. The replacement of them by the Express, a satellite of an improved design, begins this year. As a result, the traffic capacity of the satellite system will increase 4 to 5 times, and the service life of every satellite will more than doubled.

For mobile communications with automobiles, trains, and sea-going and river craft, it is planned to put into operation the Marathon system based on five new Arkos geostationary spacecraft and four Mayak satellites in elliptical orbits. By 2000 the capacity of the Marathon system will amount to 1,800-2,000 telephone channels.

Plans also provide for broadening the TV broadcasting network in 1993.

Space Potential . . .

Times

BY YURI KOLESNIKOV
RIA - Novosti

The Gals new-generation space vehicles will join it this year, and the Gals-R in 1994. All in all, five satellites of this type will be launched. For the first time this will provide regional TV broadcasting through simple individual receiving stations over practically the entire territory of Russia and the CIS member states. As a result, the national economy and the population will additionally receive about 70,000 telephone traffic channels. The number of main channels will double; 50,000 of them will be used in inter-regional communication systems and over 15,000 in rural areas. Priority will be given to the regions of the Far North, Siberia and the Far East.

At the same time, work is under way to commission several low-orbit communication systems in 1994-1995. They will be composed of the small, simple and low-cost Gonets, Kurrier, Koskon, SPS-Ural and Signal satellites designed for global communication and transmission of digital information and intercomputer exchange.

The need for accurate information on the state of the environment is particularly acute in Russia where radical reorganisation of economic relations is taking place against the background of a difficult and, in some areas, even disastrous ecological situation. At the beginning of the 1990s, the aggregate annual damage caused by unfavourable ecological situations, natural calamities and emergency situations in Russia exceeded fifty billion roubles (at 1991 prices) and, according to forecasts, it will double by the year 2000. At the same time, according to estimates by Russian and foreign specialists, at least one third of the damage could be avoided through the timely implementation of preventive and rescue work on the basis of operational information obtained specifically from space.

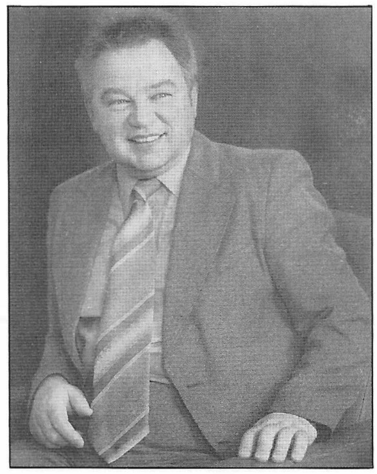
Regrettably, at the present time both foreign and Russian space systems, designed for these purposes, are at the initial stage of development only. This notwithstanding, US budget allocations for space ecology in 1993 have already topped one billion dollars. In contrast, Russia was able to appropriate only 2.5 billion roubles for space ecology and this money will be spent primarily on renewing the fleet of special satellites.

(Further details of plans for communications satellites are presented by ***Theo Pirard*** *on p.371).*

Georgii Grechko, Cosmonaut Hero

His Work and Views on Space Exploration

An Interview by
NINA MAKSAKOVA
an RIA Correspondent



Georgii Grechko.

M: You were in outer space three times - in 1975, 1978 and 1985. You were decorated with many Soviet and foreign orders and medals including some from international space organisations. You were twice awarded the Title of the Hero of the Soviet Union. Unfortunately, your name is not much mentioned today. Is fame so fleeting?

G: This is a natural process. People know Yuri Gagarin and German Titov very well. But nobody cares who was the 34th cosmonaut (this is my personal rank) or, for instance, the 205th astronaut.

In short, people know pioneers. The Wright brothers were the first American pilots who flew for 59 seconds in the plane they built. Although they flew just 100 or 200 metres they were heroes. Everybody knows their names. It's natural. Each epoch has its own heroes. Those who save mankind from cancer or AIDS will be famous for all time as well.

M: Entire sectors of the Russian population feel socially uncomfortable today? Is life easier for cosmonauts?

G: Alas, neither easy living nor quiet old age are guaranteed now for either farmers or cosmonauts.

M: We were taught to be poor. The authorities told the people that all the money was used for defence and space needs. Are our low living standards directly related to space exploration?

G: The money granted for space constitutes only one-tenth of Russia's loss in agriculture. If Russians were able to be one-tenth more efficient, space exploration would cost nothing to Russia. Expenditures on space amount to only 2 or 3% of defence spending. Money is spent to form numerous army divisions, to purchase tanks, ships, aeroplanes and fuel. Space expenditure has been sharply reduced today. Some reductions are easy to explain. For instance, the production of the Buran space shuttle was a mistake. This shuttle has no future. The Soviet Union built it because the United States had one.

M: Has the Mir station ever been modified?

G: The station needs to be modified constantly, as it becomes outdated. It has constantly been built up with units fitted with modern instruments. First, it was a living unit, used for simple research. Then there were "Kvant" and "Kvant-2" units fitted with X-ray equipment. Next came the "Kristall" unit equipped with furnaces for the production of perfect mono-crystals for electronics. Then a unit with optic instruments. Now he have the "Priroda" unit with special equipment for studying the Earth and its atmosphere.

M: Americans said once they were ready to travel to Mars with Russians in the year 2000. Will such a flight become a reality?

G: Current technology makes such a flight possible today. But Russia is facing an economic crisis and the Americans will not meet all the costs. Unmanned flights have become international and reconnaissance flights to Mars will start next year. There are 5 or 6 countries, including France and Japan, ready to participate in this research. As for manned flight it should be affordable by 2010.

M: You made a big contribution to space exploration. Were your bosses ever dissatisfied with your work?

G: Unfortunately, they were dissatisfied although I always fulfilled my flight-tasks. A space flight is always heavily scheduled. I conducted my own experiments during my leisure time. My experiments recently helped me become a Doctor of Science. When I returned from the flight my commanders criticised me. They alleged I deviated from the schedule and that it ostensibly jeopardised the programme. I tried to reply, Did I reduce the flight time or not implement the programme? But nobody wanted to hear me.

M: The astronomers of the Crimean observatory discovered a small planet and gave it your name.

G: I'm proud of that. If I were asked to make another space flight, I would go without thinking twice.

M: Let's get back to Earth. You were elected Chairman of the Federation of Peace and Accord.

G: This is an international non-governmental organisation. It was established by a number of peace-making, ecological, cultural and human rights associations from the CIS, the Baltic states and other countries. All of them are equal and independent members. Our organisation has no governmental support. Its headquarters are in Moscow.

According to UN data there are dozens of wars and hundreds of armed conflicts on the planet today including in the former USSR. Our organisation is dedicated to trying to stop them.

Satellites for the Russian Economy

The Russian Space Agency (RSA) has Unveiled Its Programmes on Meteorology, Environmental Monitoring and Remote Sounding of the Earth's Surface

Russia inherited a unique space network from the USSR, which involves five different types of mass-produced satellites, as well as two ground-based tracking stations in Novosibirsk and Khabarovsk and the Priroda data-processing centre in Moscow. Only the United States and Western Europe possess similar technological potentialities. However, satellites and ground-based tracking stations have to be equipped with newly designed data-exchange systems which are able to operate on international radio frequencies to enable prompt information to be furnished to foreign customers (and vice versa). Russia joined the international committee which supervises the aforementioned activities only last December.

BY ANATOLY ZAK
RIA-Novosti

The agency intends to use the defence ministry's hitherto top-secret spy satellites for monitoring the Earth's surface. According to the RSA deputy manager Yuri Milov, advanced Russian-made spy satellites can also be used for commercial purposes, but the specifications of these satellites do not always conform to civilian requirements. For this reason the RSA will keep working to upgrade the existing civilian satellite fleet. The new Electro satellite will be located over the equator at 78° East longitude and subsequently incorporated into an international network with American, European and Japanese satellites. Until recently, only low-orbit Meteor weather satellites have been available at Russia. These satellites rotate simultaneously with the Sun around the Earth. The Meteor network will also be kept working; a Cyclone booster placed in orbit another Meteor satellite on 31 August (***Spaceflight***, October 1993, p.353).

Data Recovery

Russia uses her Resource-F satellites, which are in 250-300 km polar orbits, to take numerous pictures of the Earth's surface for use by geologists and cartographers. These satellites are the "grandsons" of the first Soviet-made Vostok spacecraft. They are also directly related to present-day spy satellites. The Resource-F's come complete with a descent module for delivering the film cassettes back to Earth.

The RSA plans to continue launching these satellites till 1997. Later on they will be replaced by the Kuban satellite, orbital tests of which will start in 1996. The new satellite will continue to return film cassettes inside its recovery capsules. It will also contain more fuel, film and an improved orientation system. Moreover, the Kuban will have a 45-day service life, which exceeds the Resource-F flying time by nearly a factor of two.

Nevertheless, these satellites have a general drawback. It takes a lot of time to recover just one descent module. That is why foreign designers stopped using them some time ago. They prefer to transmit coded photos (and other images) by radio. The operation of the French-made Spot satellite and the American Landsat and Keyhole satellites are based on these principles. The former USSR also managed to develop satellites with a remote-controlled image-transmission facility. For its part, the national R&D institute of electric machine-building has developed a similar Resource-O civilian satellite, which is to be launched by Zenith-type boosters once every two years. Flying at 650 km above the Earth, this satellite can operate for three consecutive years and will provide clients with first-hand information.

The RSA is deeply troubled by local data-processing facilities, whose development tends to lag behind that of space technology proper and which are now hopelessly outdated. And finally, both Russia and the West have to educate their own "consumer generation", for whom the use of the satellite information could be vital. It concerns all potential subscribers from farmers to ministers of state.

Ocean Observation

A further Ocean-type satellite is to be launched by the end of the year. These satellites are used to monitor the world's ocean surface and to observe ice fields. Though this is the seventh Ocean-type launch, it might become the last because the Yuzhnoye design bureau (located at the city of Dnepropetrovsk, Ukraine), which designed and delivered these spacecraft in the past, is now plagued by financial problems. The Ukrainian government seems interested in various civilian satellites; but it does not understand the importance of the study of the polar sea itineraries for Ukraine's economy.

Almaz Programme

Another two Russian "Landsat" projects are unable to take off due to financial uncertainty. There is a jinx on the Almaz programme, which originated in the 1960s. In those days the design bureau headed by Academician Chelomei (now called the Mashinostroenyie R&D association, which is located in the town of Reutovo, Moscow region) created a military orbital station. The project was moth-balled some time later, and the bureau's experts decided to convert this spacecraft into a mapping satellite for radar-guided cartography of the Earth's surface. Two unmanned Almaz spacecraft were launched in 1987 and 1991 respectively and have impressively demonstrated their potentialities. The experience gained during these two flights has been used to design a more advanced spacecraft. However, Russia was plunged into crisis soon afterwards, and the state stopped financing the project. The NPO's management tried hard to keep the Almaz project afloat, selling the previous two spacecraft's photos for hard currency. As a result, it recouped about $100,000 for the subsequent R&D effort. NPO's experts have already completed all paperwork, finalising all forms and records by June 1993. The RSA is paying lip service to the Almaz project, but the 40 million roubles promised by the space department throughout 1993 have been of no avail. Meanwhile the designers are pinning high hopes on their Russian and foreign commercial partners.

If things work out, another 18-ton Almaz station will be launched by a Proton booster somewhere in June or July 1996. The Almaz will be orbiting the Earth at a 400-km altitude and orbital inclination 73°. Consequently, it will be able to take pictures of just about any point of the globe round the clock, regardless of weather conditions. It can also prepare stereo images of the local terrain, using radio waves to "peep" under the surface of bushy forests and deserts. The new station, which is expected to stay in orbit for, at least, three years, will store data on its Winchester disks, and send it to subscribers the world over on demand.

Mir Programme

And now a few words about the Priroda specialised module, which is due to dock with the Mir orbital station some time from now. This project seems to have fared better than the Almaz programme. The module, which is almost complete, will study the Earth's natural resources. We need just "a penny" to complete the project, the experts like to joke. RSA spokesmen have made it clear that both the Russian Academy of Sciences and foreign designers who are working on the module's instrument package would like it to be launched. The launch is expected to take place somewhere in 1994. At the same time, the heavily equipped Spectrum module, which was constructed for the former Soviet defence ministry along with the Priroda module, is now ready for lift off. However, nobody seems interested in it.

Of the long-term programmes, the RSA regards Mir and its specialised modules as a kind of test base for various types of equipment, which will be installed aboard unmanned spacecraft. The work is to proceed apace to create better research instruments for satellites; in fact, the agency regards this as a top priority.

PROTON: *Not Crewrated For Soyuz-TM Space Station Roll*

According to the Acad. S.P. Korolyov, NPO-Energlya it could take as long as three years to re-crewrate the SL-12 Assured Crew Return Vehicle (ACRV) option for NASA's Space Station. This was learned from NASA personnel working with the Russian NPO-Energiya assistant chief designer's team interfacing with the NASA Space Station Redesign team. It was presented to the Space Station Redesign Advisory Committee on May 3, 1993 in Crystal City, Virginia.

Proton was initially manrated in October 1970 with the successful launch of Zond-8 an unmanned lunar circumnavigation manned derivative of the Soyuz spacecraft test vehicle. At that time Proton only used the Block-D version of its fourth stage in which the spacecraft payload guidance system provided the guidance commands. It is believed that if a need were identified for a Proton launch of the three person crewed Soyuz-TM and uncrewed Progress-M, (with its automated rendezvous and docking system which uses the Soyuz-TM instrument propulsion module), that the re-crewrating of Proton could probably be done in a little over one year with one flight test. Two flight tests would be preferred extending that time by several months.

In March 1974, NPO Energiya introduced a new test version of Proton's fourth stage, Block-DM, which incorporated a new instrument unit with two guidance systems for the transfer orbit in launches to geostationary orbit. It became operational in 1976-77. More recently Russian space systems have been in transition from analog systems to digitalised avionics systems. Besides the inflight avionics changes and its potential cross-chatter problems there is also a structures requalification requirement for Block-D/DM.

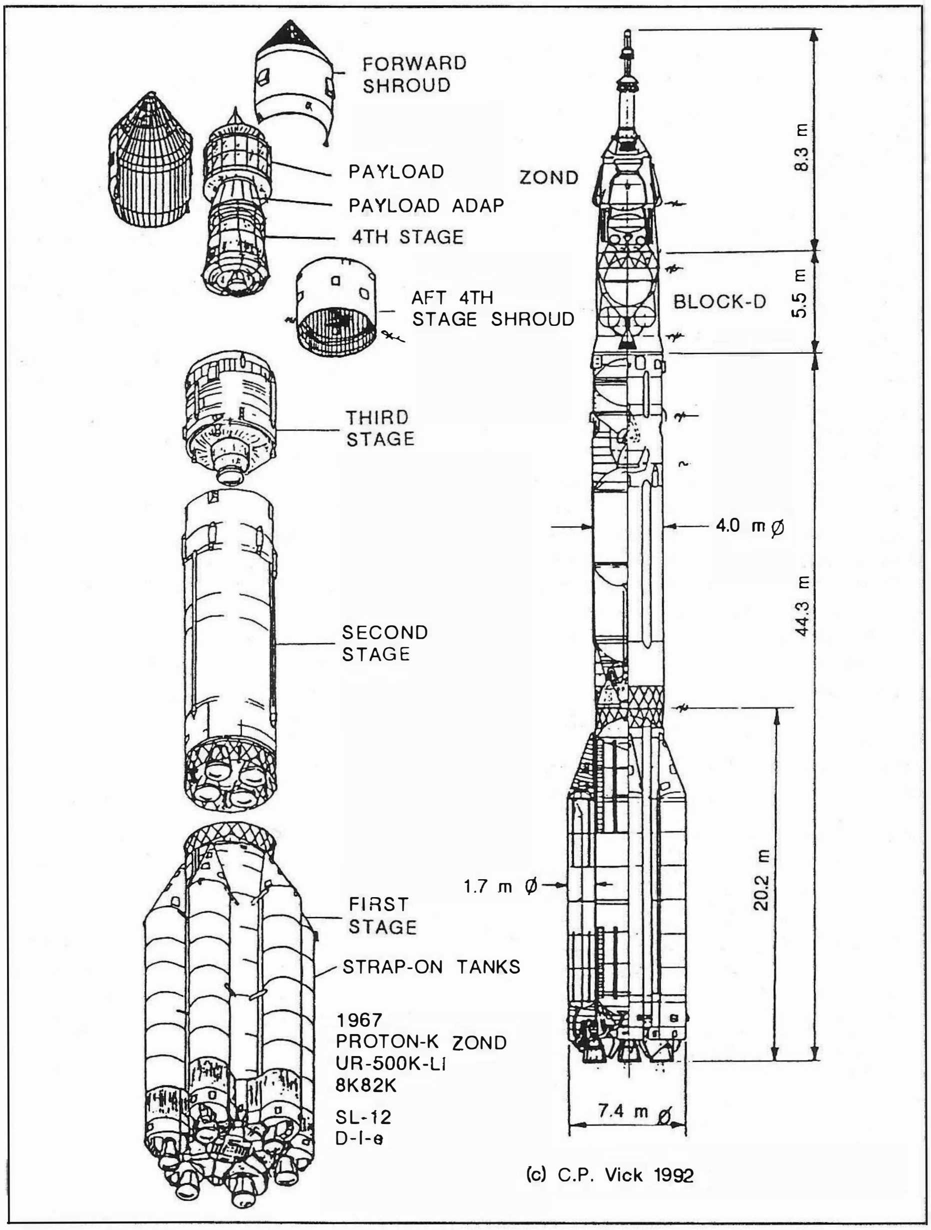
Additionally there is the extreme launch acoustics environment of 119-144 db acoustic pressure with an octavian range of 31.5 - 4,000 Hz that will have to be dealt with from the inside surface of the Soyuz-TM launch shroud, less it have an ill effect on a potential crew. Which version of the fourth stage will be used (Block-DM without the Instrument Unit or DM with the Instrument Unit) is unclear. If Block D/DM without the Instrument Unit were used it could save weight for booster performance. This in turn would require Block-DM's controlling instrumentation to be integrated with the existing Soyuz-TM design which could be very time consuming. The older first Soyuz class spacecraft no longer in production apparently carried this instrumentation in a saddle torus tank at the base of its Instrument Propulsion Module.

In reality the re-crewrating of Proton centres on the Block-D/DM relationship to Soyuz-TM and not the first three stages of Proton which were requalified for crewed flight with the launch of the double Kosmos, Kosmos Modules in the late 1970s. From the very first, Proton was designed in the early 1960s for crewed flight. If Soyuz-TM or Progress-M were launched by Proton it would be possible to place its payload on an orbit of inclination as low as 33 degrees. Unfortunately this in turn produces a political problem for the Russians and the Kazakhstanes in that they would be launching over the Peoples Republic of China which both they and the United States would have to deal with. Presently Proton can only be launched from the Baikonur Cosmodrome in the Republic of Kazakhstan which owns the facilities.

The systems life of Soyuz-TM must be extended from the order of no greater than 200 days plus in space to a full two years with the American aerospace industry's assistance or redesign.

KB-Salyut the former V.N. Chelomei OKB-52 owns the Proton design intellectual property rights while Khrunichev is its former dedicated factory trying to be a design bureau. Even more interesting is the fact that the CIS Strategic Space Forces associated with Glavkosmos are the personnel that will ultimately launch all CIS rocket. All of these various factions are fighting for the control of the monies to be obtained from Proton's services. President Yeltsin should know full well that, if all these factions cannot work out these problems they stand the strong probability of loosing all potential business possibilities from around the world. It is equally apparent, that if a compromise cannot be worked out on the Space Stations launch inclination with Freedom then a US commercial launch vehicle will be required if a need for Soyuz-TM and Progress-M is identified.

Eventually a Proton launch facility will be built on the Northern Cosmodrome of Plesetsk probably utilising one of the four existing Soyuz pads or a new launch facility. ***(c) Charles P. Vick 1993***



(c) C.P. Vick 1992

KB Photon Releases "Rus" Modified Soyuz-TM Booster Details

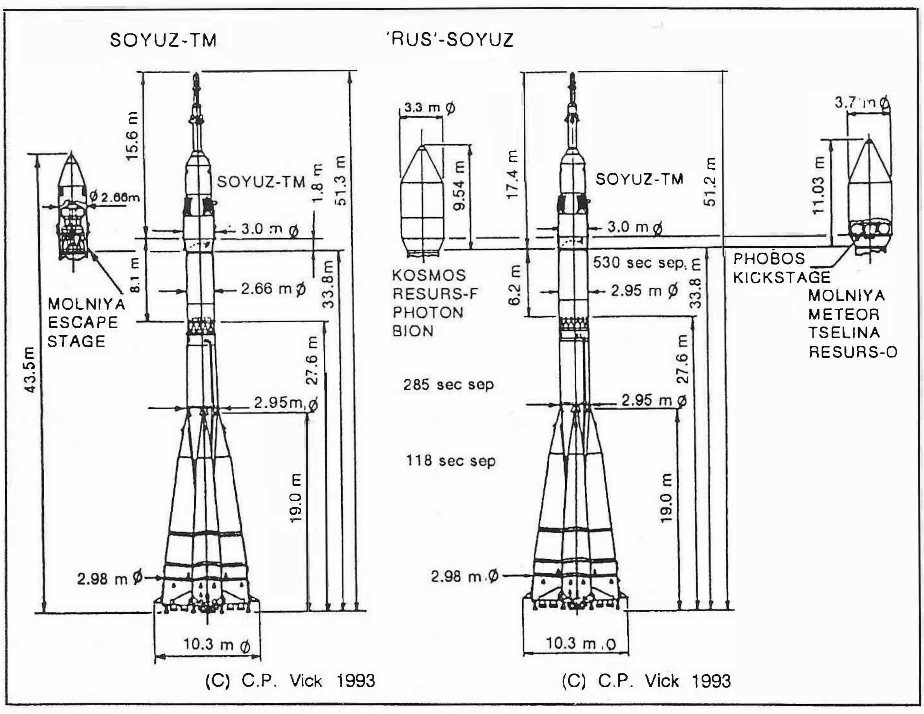
In 1991 KB Photon, formerly NPO Energiya's dedicated factory located in Samara, Russia received a contract for the Russian Space Agency to produce by January 1996 a modernised standardised replacement version of the Vostok, Molniya, and Soyuz booster to be called "Rus". This will mean that these three boosters will be put out of production between 1996 and the year 2000 as expected.

Derivatives of the basic R-7 Sputnik booster have been in production since 1956 or for over 40 years by 1996. The newer versions will extend production well beyond the year 2000 of this basic highly reliable booster. Russia's ability to offer lower cost for their space launch services in the commercial space market place is explained by the long-term large production run and full life-cycle mission costing of such standardised boosters. The Rus booster in its various forms is expected to begin flight testing in 1996, 1997 or typically the middle of the next Russian five year plan.

General modernisation improvements to this booster will allow it to increase its payload carrying capacity by the order of between 500 and 800 kg. Presently the Soyuz-TM spacecraft mass is 7,070 kg. The Soyuz booster was originally designed to carry 7,500 kg to a standard reference orbit. Additional requirements from the Russian Space Agency were that this booster be able to carry a manned Soyuz-TM spacecraft from the Plesetsk, Northern Cosmodrome to the Mir-2 space station in a 62/65 degree inclination orbit and that the booster still be compatible with the existing Molniya/Soyuz launch facilities with as few modifications as possible. There are four Soyuz pads at Plesetsk and three at Baikonur now called Tyuratam Cosmodrome.

The present time-scale requirement for the Mir-2 launch capability is 1996-1997. KB Photon was also asked to adapt two existing Proton booster shrouds to the Rus booster for various spacecraft as shown in the accompanying illustration by the author, illustrator Charles P. Vick. The existing Soyuz/Molniya booster will have general airframe, propulsion and guidance onboard avionics improvements carried out on its sustainer core second stage and its third stage. The old Molniya escape stage performance, will be totally replaced by the Phobos kick stage. It is a modification of the existing Phobos mid-course and orbit insertion stage already proven to be very reliable. It uses storable toxic propellants. From the existing drawing released by KB Photon it is apparent that the last stage of the Soyuz booster will have its body diameter increased from 2.66 metres to 2.95 metres as will the top half of the second-stage sustainer core. The last stage will utilise an improved RD-461 of 30 tonnes vacuum thrust. Launch thrust for the Molniya/Soyuz booster is 410/418 tonnes force and the launch mass is 306/310 tonnes. All stages except for the Phobos kick stage will use kerosene lox as before.

(c) Charles P. Vick 1993



Russians Plan to Collect Phobos Sample

In 1998 a Russian robot should fly to the Martian moon Phobos, drill up a sample and bring it back to Earth. This new project is being proposed by Dr Eric Galimov, the new director of the Vernadsky Institute for Planetary Research in Moscow. Unlike his predecessor Prof Valery Barsukov, who died recently and proposed collecting Martian soil, Galimov thinks the time for such a complicated adventure has not come yet.

Dr Oleg Yakovlyev of the Vernadsky Institute thinks the new choice is a realistic one: "It is a lot easier and less risky to get a Phobos sample than Martian soil. Phobos is small and has a weak gravity field. In fact it is more like 'rendezvous and docking' with Phobos than landing there in the classical sense. If you go to Mars you have to go through its atmosphere, you need a lot of energy for the landing and especially for take off.

Phobos, which orbits Mars at an altitude of just 6000 km, measures only 20 km across and its attraction is so weak that a 70kg man would weigh only 63 *grams* there. A landing robot would first of all attach itself firmly to the ground before starting to drill. With a minimal effort it could detach itself, orbit Mars again and then fly back to Earth.

From a scientific point of view a Phobos sample would be quite different from Martian soil. Phobos is most probably a former asteroid. Its material should represent the original ingredients from which the planets were formed. Mars on the other hand is a planet with its own complicated geological history, internal processes, water and erosion.

In 1994 and 1996 the Russians are still planning to launch Mars orbiters, landers (including a small rover) and a balloon which will drift in the Martian atmosphere. Only after the turn of the century will an attempt be made to collect Martian soil and bring it to Earth. ***Peter Smolders***

Ukraine's Space Programme

Ukraine's National Space Agency (NKAU), announced recently that Ukraine plans to launch its own satellite in 1994.

NKAU asked for an allocation of 36 billion karbovantsi (Ukrainian currency) for the programme. NKAU's priority is the establishment of a national system of space communications and satellite environmental monitoring. It will also be involved in the development and improvement of commercial space transportation systems and infrastructure. NKAU was counting on receiving 77 billion karbovantsi, but only 38 billion remained in the draft budget under preparation.

Ukraine is working on a space programme with three stages: the first envisages further integration with Russia and Kazakhstan; the second casts Ukraine in the role of consumer and producer on the world space market; and the third is an international one involving cooperation with countries outside CIS. ***Theo Pirard***

Space Communications in the CIS

More than 30 Spacecraft to be Launched by Proton

In 1993, the Republic of Russia will invest some 17 billion roubles (one-third of the total budget for civilian space activities) in the development of communications satellites. The Commission of the Russian Parliament for transportation, communications, computers and space is preparing two laws which will define the role of public agencies and private enterprise in the field of space applications.

The existing systems, using aged technology (developed during the 70's) are currently based upon:

- Ten Gorizont-type communications satellites with C-band and K-band capacity;
- Two Ekran-type direct broadcasting satellites with high-power repeaters in UHF.

Built by NPO PM (Applied Mechanics) at Krasnoyark (Siberia), they are launched by the Proton using the DM Block upper stage. According to Mikhaïl Rechetnev, chief engineer at NPO PM, the existing satellites have limited resources, use a small number of repeaters, have a short lifetime (only 3 years in orbit in the best case), and no North-South attitude control in geosynchronous location. He explained that the slow progress in the field of communications satellites technology was due to the priority that had been given to the development of the Energiya-Buran space transportation system.

In the immediate future, new spacecraft will be launched but they do not yet meet the standard and performance of Western technology:

- Ten Express communications satellites are being prepared to replace the Gorizont series; the first one will be launched in late 1993 or early 1994. They will have improved capacity, a better attitude control accuracy and orbital lifetime of 5 years, hopefully 7 years. NPO PM is already working on the Express-M (M for modernized) series: four are planned to be ready for launch in 1996.
- Five Gals direct broadcasting satellites with Ku-band capacity will replace the Ekran satellites. First Gals will be launched during this summer. Kazakhstan, Uzberkistan and Bachkortostan are interested in participating in the use of the Gals system.
- Five geosynchronous Arkos and four medium-orbit (Glonass orbit) Maïak spacecraft will form the Russian Marathon system of space navigation and mobile communications; Russia plans to launch them in 1994-1996.

Joint ventures that are being developed with technological and financial support from the West are:

- The Sovcanstar system is being developed jointly by Russian and Canadian firms; it will consist of using up to five satellites in geostationary orbit for domestic and international links. While the platform is being built by NPO PM Krasnoyark, the sophisticated payload with Ku-band capacity is being developed by SPAR Aerospace in Canada. The first satellite is planned for launch in 1995.
- The Globostar system of Ku-band communications satellites, named Coupon (formerly Bankir), is a venture of Russian banks and firms which have established the Global Information Systems Inc. A British subsidiary, Globostar Satellite Systems Ltd, based at Hong Kong, is the marketing agent for the services of the Globostar system which will directly compete with Intelsat and PanAmSat. Five satellites, each with 16 high-power transponders for a lifetime of up to 8 years (using technology identical to the Eutelsat I generation of the 80's), are being developed by NPO Lavochkin of Moscow and designed for VSAT operations; the first one will be launched by Proton in January 1994 and positioned at 55 degrees East for Ku-band communications in CIS and Eastern Europe.
- The Zercalo (Mirror) system with a first Ku-band communications satellite is to be launched in early 1995 and is another commercial venture developed by Noos Space Technologies (NST) of Moscow. This new company was formed by Noos Py Ltd with military production organizations, NPO Lavochkin and NPO Automated Instruments. Zercalo is a 3.1 t spacecraft with 10 medium-power Ku-band transponders and with 10 beams (8 fixed and 2 mobile). Developed also by NPO Lavochkin, a prototype will be located in 1995 at 88.1° East for a 5 to 7 year lifetime. Zercalo-1 will be used especially for the development of VSAT services in CIS, China, India and Australia.

For the next three years, this schedule represents for the Russian Proton launch vehicle the placing of some 35 spacecraft in geosynchronous locations. At more than 10 launchers per year, the question arises 'Can the Proton vehicle still be available for commercial use ?'

Theo Pirard

BOOK NOTICE

Euroconsults Space Directory of Russia

Sevig Press, 6 Rue Bellart, F-75015 Paris, France, 1993, 359pp, $375.

The Russian Space Industry is hard to identify and hard to access owing to its complicated structure and the recent rapid proliferation of agencies and companies.

This directory, conceived as a business tool, is most comprehensive, listing close to 550 government and industry organisations. It is based on in-depth missions to the Soviet and Russian space worlds in 1989-1992, over 250 interviews, an analysis of thousands of official documents and articles in 200 international and trade journals. The text is undiluted by glossy illustrations, histories of space flight or lists of cosmonauts. It is fully referenced and can also be used by the academic researcher.

Access is made by company name and by executive name (former USSR bodies are listed too), or by type of activity viz: government, communications, navigation, transportation, manned programmes, Earth observation, equipment manufacturers, insurance/finance etc.

For further Book Notices see p.394.

Mir Spacewalks

The two Mir cosmonauts Vasily Tsibliyev and Alexander Serebrov took a nearly two-hour spacewalk on 28 September to replace equipment on the Mir space station. This followed a three-hour spacewalk on 20 September as work continued to test construction materials in space. The operation was aimed at developing ways to unfold large-sized construction materials in space. In a spacewalk during the previous week, the cosmonauts assembled a grate on a module attached to the Mir space station and then installed a platform on the grate to hold equipment to be used in further experiments on the influence of space on construction materials.

Mosaerospace Show '93 - see p.383.

SATELLITE DIGEST-258

Satellite Digest is our regular listing of world space launches. It is abridged from a more detailed monthly listing, Worldwide Satellite Launches prepared by Phillip S. Clark and published by the Molniya Space Consultancy.

Spacecraft	Int'l Desig.	Launch	Launch Site	Launch Vehicle	Mass kg	Orbital Epoch	Inclin. deg	Period min	Perigee km	Apogee km	Notes
[No Name]		Aug 2.83	WR	Titan-4	12,000 ?		Failed to reach orbit				[1]
Molniya-3 45	1993-049A	Aug 4.04	Plesetsk	Molniya	1,750 ?	Aug 9.45	62.80	717.53	412	39,931	[2]
NOAA 13	1993-050A	Aug 9.42	WR	Atlas 34E	1,030	Aug 9.75	98.31	102.07	850	863	[3]
Cosmos 2261	1993-051A	Aug 10.62	Plesetsk	Molniya	1,900 ?	Aug 13.64	62.89	717.52	582	39,760	[4]
Progress-M 19	1993-052A	Aug 10.93	Tyuratam	Soyuz	7,250 ?	Aug 13.05	51.62	92.36	387	393	[5]
Resurs-F 19	1993-053A	Aug 24.45	Plesetsk	Soyuz	6,300 ?	Aug 25.24	82.59	89.08	224	234	[6]
Navstar 22	1993-054A	Aug 30.53	ER	Delta-2	1,881	Aug 30.88	35.85	356.52	196	20,359	[7]
Meteor-2 21	1993-055A	Aug 31.40	Plesetsk	Tsyklon	2,000 ?	Sep 1.05	82.55	104.12	938	969	[8]
TEMISAT	1993-055B				30	Sep 1.19	82.55	104.11	937	969	[9]

NOTES

1. Classified Department of Defense payload: press reports suggested that three White Cloud ocean surveillance satellites were on board, in which case a much larger satellite (an advanced KH-11 ?) would also have been carried. Explosion, caused by problems with a strap-on booster, caused the launch vehicle's destruction about 120 seconds after launch at 19.59 GMT.

2. Communications satellite, co-planar with Molniya-3 37. Actual launch time was 00.52 GMT.

3. Meteorological satellite, launched to replace NOAA 11. An on-board failure prevented electrical power being received from the solar panels. NOAA 9 was later re-activated as a stop-gap measure.

4. Oko series early warning satellite, co-planar with Cosmos 2050. Actual launch time was 14.54 GMT.

5. Unmanned cargo freighter, docked at the rear Kvant 1 port of the Mir Complex, Aug 13.00 (approximately 00.00 GMT). Actual launch time was 22.23 GMT.

6. Recoverable Resurs-F1 class remote sensing satellite.

7. Thirteenth launch of a Block 2A Navstar satellite, also known as USA 93. Actual launch time 12.38 GMT.

8. Second generation meteorological satellite.

9. TEMISAT (Telespazio Micro Satellite) is an Italian project with the payload built by Kayser-Threde in Germany, planned to demonstrate a commercial data relay service. Launched "piggy-back" with Meteor-2 21.

ADDITIONS AND UPDATES

1967-043B Hitchhiker 14/OPS 1967 decayed 1993 Mar 14.

1977-005A NATO 3B was boosted off-station in geosynchronous orbit during July and has probably been retired.

1983-089B INSAT 1B was boosted off-station in geosynchronous orbit over 93°E at the end of July and it was awaiting the re-stabilisation of its orbital location a month later.

1983-123A Molniya-3 22 decayed from orbit Aug 18.

1985-109C At the beginning of July Optus-A 2 was boosted off-station in geosynchronous orbit over 160°E: a month later the orbit was re-stabilised over 164°E.

1989-004A At the beginning of August Gorizont 17's longitude in geosynchronous orbit was re-stabilised over 133-134°E.

1989-053A During the night of Aug 11-12 control of Olympus 1 was lost. Two weeks later it was announced that attempts to regain control had been abandoned and the satellite had been boosted into an orbit below the geosynchronous altitude.

1989-089A During 1993 COBE has started to shed fragments, but this does not appear to have affected the satellite's operations: to the end of August additional objects 1989-089E-AM have been tracked.

1991-010A In late August the drift rate of Cosmos 2133 was reduced by an orbital manoeuvre, suggesting that the satellite was to be re-located over 80° in the geosynchronous orbit band.

1992-063A Contact with Mars Observer was lost on Aug 21: the fate of the spacecraft is unknown - it might have been destroyed following a propellant tank over-pressurisation or it could have flown past Mars intact but silent.

1992-088A Approximately Aug 12 the drift rate of Cosmos 2224 was reduced as the satellite was over 338°E in the geosynchronous orbit band: the satellite is now slowly drifting towards it new operating longitude of 335-336°E.

1993-019A Progress-M 19 undocked from the Mir Complex Aug 11.65 (15.36 GMT) and was later de-orbited.

1993-026A Add the following orbital data for ALEXIS: Jul 30.59, 69.93°, 100.69 minutes, 747 km, 836 km.

1993-047A The name of this satellite is confirmed to be Cosmos 2260, the first Resurs-T to be identified. Launch calculations suggest a launch time closer to Jul 22.36 (08.44GMT) than the announced 08.56 GMT. Descent module recovered approximately Aug 5.2.

1993-048A Add the following orbital data for HISPASAT 1B: Aug 17.01, 0.02°, 1,436.08 minutes, 35,778 km, 35,795 km. Satellite initially located over 330°E

1993-048B Add the following orbital data for INSAT 2B: Aug 5.87, 0.20°, 1,436.16 minutes, 35,769 km, 35,807 km. Satellite initially located over 93°E.

STS-51 - Discovery Successfully Launched After Delays

First Night Landing at KSC for the Space Shuttle Program

Discovery was launched on mission STS-51 at 7:45 am EDT on the morning of September 12, 1993 after experiencing three launch scrubs and a delay to allow the Perseid meteor shower to pass by.

The initial STS-51 launch attempt was scrubbed on July 17 due to a faulty circuit card controlling pyrotechnic circuits for the right hand Solid Rocket Booster (SRB) holddown bolts [1]. The circuit card, which was actually located in the launcher platform and not in the Shuttle itself, was replaced. A second launch attempt on July 24 was halted at T-19 seconds when a hydraulic power unit on the right hand SRB experienced trouble with the rate at which a turbine was coming up to speed.

Following the replacement of the unit, the launch was initially rescheduled for about August 4. However, on Friday July 30, NASA mission managers decided to postpone the launch until August 12. The delay was due to concerns regarding the Perseid meteor shower which was expected to peak on the evening of August 11. Had STS-51 launched on August 4, Discovery would still be in orbit on the evening of the 11th. Although the chance of the orbiter actually being struck by one of the meteors was very small, managers elected not to take that chance.

The countdown for the rescheduled launch of the Space Shuttle Discovery on mission STS-51 began at 9:30 am August 9 with the countdown aiming for a launch at 9:10 am on August 12th. All three engines ignited but at launch minus 3 seconds a flow meter sensor on engine number 2 (lower left) failed and the Shuttle's onboard computers shut down the engines and aborted the launch [1].

Since all three engines had fired, programme managers dictated that the three engines should be removed and replaced with those slated for the STS-60 mission - also a Discovery flight. The faulty sensor was removed and tests at the vendor duplicated the sensor failure under cryogenic conditions.

September 10 was selected as the new launch date and processing of the Shuttle and its payload continued as scheduled. However a failure in the Mars Observer spacecraft and the NOAA-13 weather satellite caused concerns over components in the STS-51 mission. An independent review team was engaged in assessing the design, production and testing heritage of the Advanced Communications Technology Satellite (ACTS) and an additional two days delay gave the team time to complete their review and verify that the payload was ready for launch. The launch was then set for September 12. At 8:00 am on September 9 the countdown began and included 28 hours and 45 minutes of built-in-holds (BIH) leading to the opening of the launch window at 7:45 am on September 12.

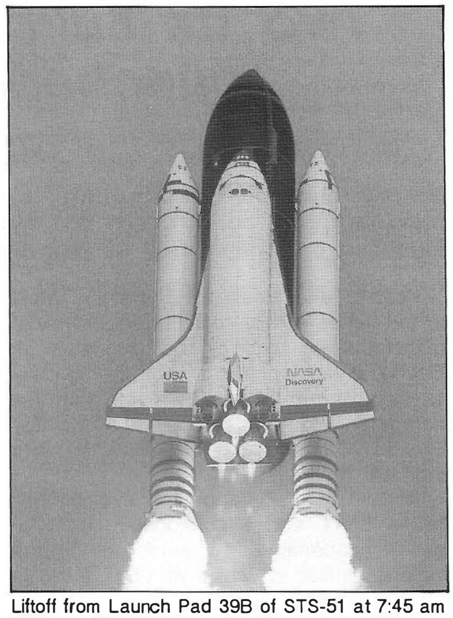
At a planned BIH of one hour at the T-6 hour mark on September 11 final preparations for external tank loading were accomplished and the Mission Management Team met to assess the weather and give a "go" for tanking.

Chilldown of the lines that carry the cryogenic propellants to the external tank began with the end of this BIH and filling and top off of the external tank was completed by the T-3 hour point. A 2-hour BIH was then entered during which the ice inspection team conducted a survey of the external tank's outer insulation and other Shuttle components. Also, the closeout crew returned to the launch pad and began configuring the crew module and the pad's retractable white room for the flight crew's arrival.

The five-member STS-51 flight crew was awakened in their quarters during this period and, following their breakfast, received a briefing on weather conditions at KSC and around the world. The crew then put on their partial-pressure flight suits and left their quarters at about 4:30 am, to be driven to the launch pad and begin entering Discovery at about 5:00 am.

The last two BIHs were 10 minutes in duration and came at the T-20 and T-9 minute points. During the final hold, the flight crew and ground team received the NASA Launch Director's and Mission Management Team's final "go" for launch.

On resumption of the countdown at T-9 minutes the Ground Launch Sequencer took over the countdown. Retraction of the personnel access arm and white room began at T-7:30 minutes; Auxiliary Power Units were activated at T-5 minutes; pressurisation of the liquid oxygen tank inside the external tank began at T-2:55 minutes; and pressurisation of the liquid hydrogen began at T-1:57 minutes. At T-31 seconds the onboard computers started their own countdown sequence and the three main engines began their start sequence at T-6.6 seconds.



Liftoff from Launch Pad 39B of STS-51 at 7:45 am EDT on 12 September 1993. *NASA*

Liftoff of STS-51 came as planned at 7:45 am as the two Solid Rocket Boosters (SRBs) ignited and at two minutes four seconds the two SRBs separated from the External Tank. Main engine cutoff came at eight minutes thirty seconds and the External Tank separated from the orbiter eighteen seconds later. Forty-two minutes after liftoff the manoeuvring engines imparted approximately 221.5 feet/second of Delta-V and Discovery was in its 161 by 160 nautical mile orbit at 28.45° inclination.

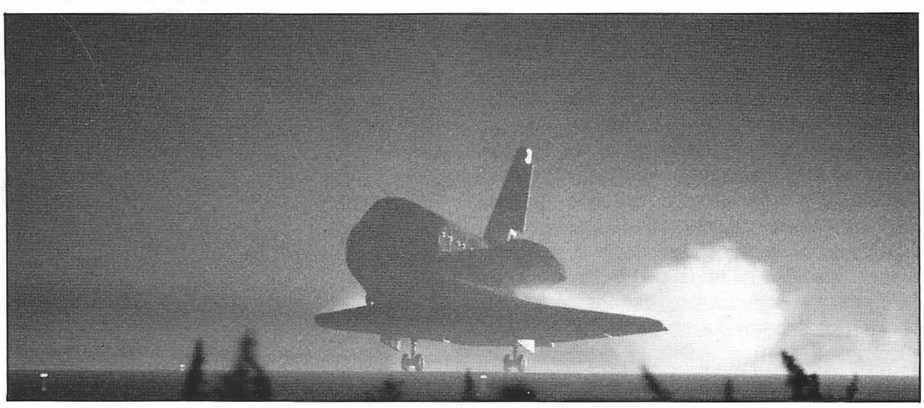
Roelof L. Schulling

Reference

1. ***Spaceflight***, September 1993, p.304.

(A full STS-51 Shuttle Mission Report is due to appear in a forthcoming issue.)

Touchdown of Discovery on Runway 15 of the Shuttle Landing Facility marks the first night landing at KSC for the Space Shuttle program. Main gear touchdown occurred at 3:56:07 am EDT on 22 September 1993 bringing to a close the highly successful Mission STS-51. *NASA*



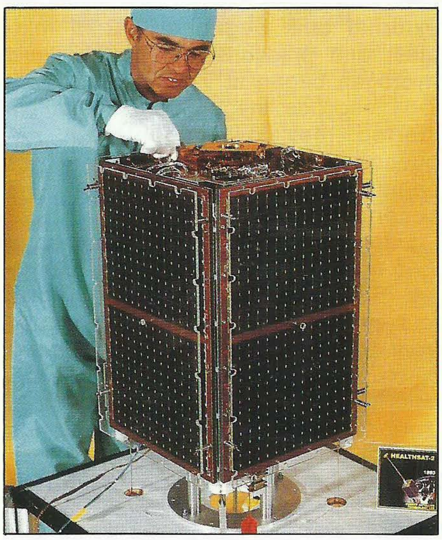
Two UK-Built Microsatellites Launched by Ariane

Britain Leads the Way in Low-Cost Satellites

Surrey Satellite Technology Ltd, Europe's leading microsatellite manufacturer, constructed the microsatellites Posat-1 and Healthsat-2 launched on Ariane V-59 as reported on the opposite page.

Posat-1 and Healthsat-2 are the latest in the series of low cost but sophisticated microsatellites built at the University of Surrey under contracts with the University's commercial technology transfer company - Surrey Satellite Technology Limited (SSTL). Each was built for less than £2 million.

Posat-1 is a collaborative mission between SSTL and a consortium of Portuguese academic and commercial organisations similar in scope to SSTL's highly successful collaboration with South Korea which led to the launch of the first Korean microsatellite, Kitsat-1, in August 1992 (***Spaceflight***, July 1993, p.246). Posat-1 is a multi-payload research mission and carries a variety of payloads. A team of seven Portuguese engineers have been working at SSTL on Posat-1 alongside the Surrey team as part of the overall programme's on-the-job training and technology transfer. SSTL engineers installed a new control ground station facility in Portugal in June in preparation for the in-orbit control of Posat-1 after launch.



Healthsat-2, a commercial store-&-forward satellite for medical communications. *SSTL*

Healthsat-2 has been built by SSTL as a commercial microsatellite mission for the US organisation SatelLife Inc to join Uosat-3/Healthsat-1 in their HealthNet programme providing medical and health communications for developing countries. SatelLife has licences in 18 developing world countries and Healthsat-2 will become the second satellite in the HealthNet system. Healthsat-2 has been designed as a dedicated store-&-forward communications mission with significantly increased on-board message capacity (32 Mbytes) and data rates (38.4 kbps) and with a communications link designed to support the use of very simple, low cost, portable ground stations.

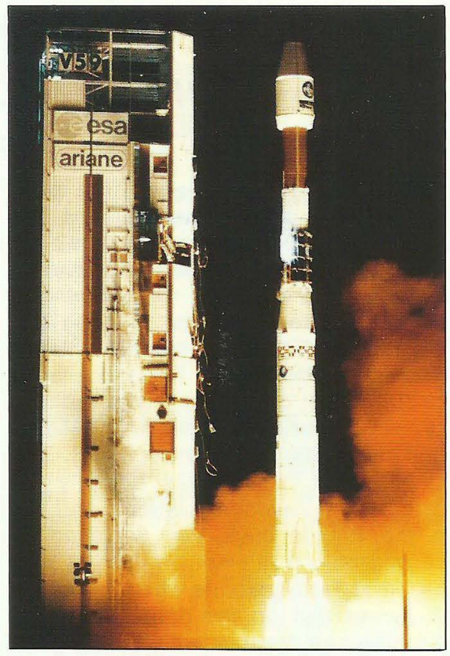
A third microsatellite, Kitsat-2, is British-designed and is part of a technology-transfer programme between Britain and South Korea.

The University of Surrey formed SSTL in 1985 to provide affordable access to space, and to win industrial funding for the University's spacecraft engineering research programme. In the past, SSTL's satellites have been used to test new computers in space, to take pictures of the oil fires in Kuwait, and to monitor space radiation.

SSTL's microsatellite sales have become a British high-tech success story: SSTL won a Queen's Award for Export in 1991; in 1992 the Her Majesty laid the cornerstone for the University's new Centre for Satellite Engineering Research; and already three microsatellites have been built in the Centre's new facilities. SSTL contributed £1.5 million recently toward the construction of the Centre, which is equipped with clean rooms and laboratories for small satellite research and development.

According to Professor Martin Sweeting, SSTL Technical Director, "SSTL clearly demonstrates how Universities, working closely with industry, can achieve both academic excellence and commercial success".

The low-cost space industry is gathering momentum in the United States and in Europe, but Britain's Surrey Satellite Technology Limited is the only company with eight microsatellites in orbit and another (CERISE) undergoing final flight acceptance tests on the ground and due for launch in 1994.



The launch of Arianespace flight 59 from Kourou, French Guiana, September 25, 1993. *Arianespace*

TEMISAT Update

By two weeks after its launch on 31 August (***Spaceflight***, October 1993, p.353), the in-orbit tests of TEMISAT were almost complete.

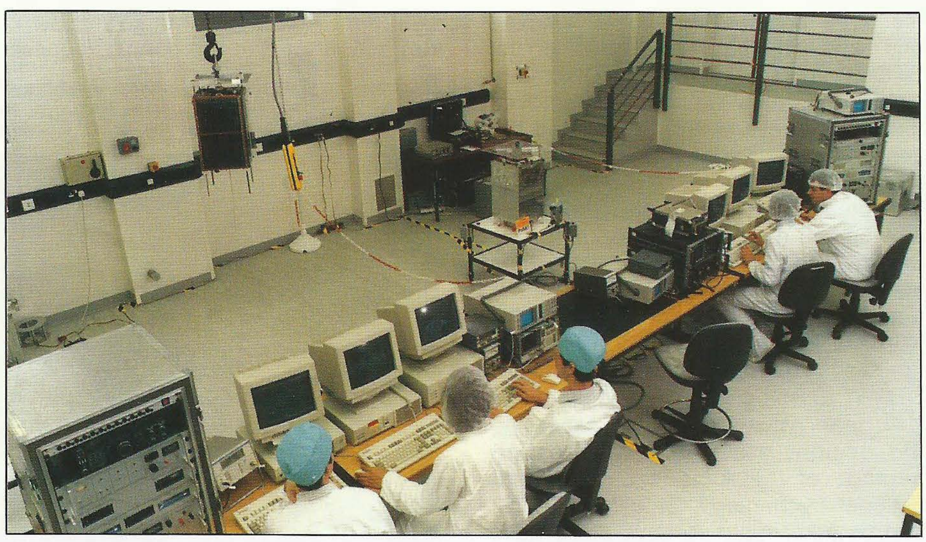
Its separation from METEOR-2 left TEMISAT in a controlled, slowly decreasing spin at a frequency of about 1 revolution/minute.

After the spin of the microsatellite has been sufficiently reduced, the magnetometers for position stabilisation will be activated. The position of TEMISAT will then be stabilised with the help of the magnetic field of the Earth. Simulations, that were performed before the mission, predicted a slow oscillation of the satellite, induced by the magnetic field of the Earth, with respect to orbit altitude and inclination.

TEMISAT is in a circular orbit with an altitude of 950 km and an inclination of 82.5°.

Keyser-Threde

Healthsat-2 (hanging with solar arrays mounted) and Posat-1 (stacked on table) in the new Assembly, Integration and Testing Clean Room facilities at the Centre for Satellite Engineering Research at the University of Surrey. *SSTL*



Launch Report

China's Long March Launch Programme

Recoverable Satellite Launched

China successfully launched a recoverable scientific research satellite from its space centre in southern Sichuan province on 8 October. The satellite, designed by the China Academy of Space Technology and having a weight of 2,100 kg was carried on a Long March 2C launcher. Eight minutes after lift off it separated from the booster and entered an orbit more than 200 km above the Earth.

The satellite is the 15th of a series of recoverable satellites to be launched by China. The recovery rate for the previous 14 satellites has been 100 percent.

Failure Investigation Closed

A seven-month investigation has found "no reason" to blame China's Long March 2E rocket for the loss on 21 December 1992 of the $138 million Optus B2 satellite, built by Hughes Aircraft of the United States and owned by Australia's Optus Communications. The investigation was conducted by specialists from Hughes and China's Great Wall Industrial Corporation, the firm charged with promoting Chinese launchers as an alternative to more expensive US and European space services. Hughes and China had previously blamed each other's technology for a small mid-launch explosion that altered the rocket trajectory and sent the satellite spinning off course. The two sides closed their investigation in mid-August and agreed to try again with a replacement satellite during the first half of 1994.

SPACE PROBE DIARY
4 October 1993

Galileo

The Galileo spacecraft is beginning a five-day trajectory correction manoeuvre to aim it directly for Jupiter for the first time in the flight. The manoeuvre will entail a total of about 10,000 pulses from the lateral thrusters to change the veloicty by 38.6 metres per second, partly increasing the speed and partly changing the direction. The daily changes are commanded from the Deep Space Network station near Canberra, Australia, and are scheduled to take place over the stations at Goldstone, California and at Canberra. Galileo is almost 479 million km from the Sun, and its speed in orbit is 16.5 km per second. The spacecraft has travelled about 55 million km since its encounter with asteroid Ida, and there are still 663 million km to go to reach Jupiter. Galileo's health and performance are excellent.

Ariane Launcher Deploys Satellites

On the night of September 25-26, 1993, Ariane V59 successfully placed into orbit Spot-3, the third Earth Observation satellite of the French Space Agency, CNES, as well as a scientific satellite called Stella for CNES and five auxiliary passenger payloads (Healthsat, Kitsat-2, Posat-1, Exosat-1 and Itamsat).

The launch vehicle was an Ariane 40, a version of Europe's launcher without strap-on booster and lift off from the Space Center in Kourou, French Guiana, was on Saturday, September 25, 1993 at 22:45:00 local time.

The launch followed a 24-hour delay because of bad weather. Seventeen minutes after lift-off, the Ariane 40 rocket released the 1.9 tonne Spot-3 Earth Observation satellite into space.

Spot-3's tasks include map making, urban planning, geology, agriculture and forestry and will replace older satellites of the same (Spot) series now in orbit but coming to the end of their useful life. These satellites have been used for military surveillance, notably during the Gulf War.

Two minutes after Spot's separation from the Ariane rocket, Stella, a 48 kg satellite, was released into space. Stella's mission will be the study of the Earth's gravity field and is designed to operate for 2000 years. Finally, 24 minutes after launch five microsatellites with a total weight of 163 kg were put into orbit. This payload consisted of:

- Kitsat-2 (Satrec, Korea), an experimental technology and telecommunications satellite. Now orbiting as Uribyol (Our Star) 2 with an expected life of five years, it follows into orbit Uribyol 1 which was launched from the same base on a similar mission on 10 August 1992. (*Spaceflight*, July 1993, p.246).
- Posat-1, the first Portuguese satellite, designed to develop space applications by the Portuguese industry.
- Healthsat-1 (UK - US), a "humanitarian" satellite designed to provide information to medical schools and health documentation centres in Africa.
- Eyesat-A (Interferometrics, US), an experimental satellite for the positioning and monitoring of industrial equipment.
- Itamsat, for the Italian association of amateur radio operators.

Provisional parameters at third stage injection into sun-synchronous orbit were:

Perigee:	791 km (± 10 km) for a target of 794 km
Apogee:	814 km (± 10 km for a target of 813 km
Inclination:	98.70° (± 0.05°) for a target of 98.74°

The next Arianespace launch, currently scheduled for 21 October will be Flight 60 and will use an Ariane 44 LP to launch the first Intelsat VII series satellite into geostationary transfer orbit for the International Telecommunications Satellite Organisation, Intelsat.

Landsat 6 Lost after Launch

Ground controllers have been unable to establish contact with the Landsat 6 Earth Observation satellite after it was launched into orbit on 5 October aboard an Air Force Titan II rocket. The satellite separated properly from the rocket after lift-off from Vandenberg Air Force Base but then failed to respond to communications. According to one theory, the Titan rocket put the Landsat 6 into a perfect elliptical orbit, but the satellite's positioning system was faulty and so the kick motor that was supposed to circularise the orbit caused it to reenter.

An official investigation has been launched with Thomas E. McGunigal, manager of NOAA's geostationary operational environmental satellite program, to head a panel of experts to look into the failure of Landsat 6. The satellite was designed and built by Martin Marietta Astro Space which already has convened a board to investigate why the spacecraft disappeared.

Landsat 6 has been the fourth project to fail in two months. The first on 2 August was a Titan rocket that exploded. Nineteen days later, NASA's Mars Observer went silent and a NOAA-13 weather satellite experienced an electrical failure. The three satellites were produced by Martin Marietta Astro Space. The Titan 4 rocket that exploded was built by Martin Marietta.

Polar Satellite Launch Vehicle Fails on Maiden Flight

India's newest and most powerful rocket, the Polar Satellite Launch Vehicle, failed to place a remote-sensing, reconnaissance-capable satellite in orbit on 20 September despite a perfect launch.

The mission failed because a disturbance during the third-stage ignition affected the PSLV's upward velocity. After reaching a height of 350 km, the uppermost rocket section and the Indian-made IRS-1E satellite which it was carrying fell back into the sea off Sri Lanka.

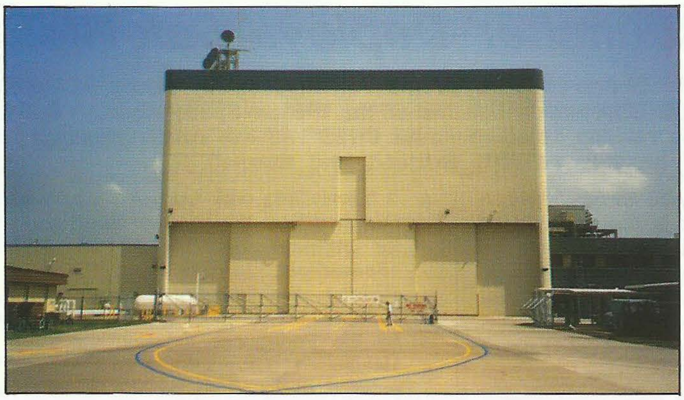
ESA Selects Rosetta Mission

ESA has recently accepted the Rosetta comet mission within the framework of its "Horizon 2000" scientific programme. The original proposal to return a sample of a comet to Earth has been dropped and the mission to be planned is for a comet rendezvous with the possibility of a comet lander.

Forthcoming STS Launchings

Mission	Launch Target Date	Orbiter Vehicle
STS-61	Early-December	Endeavour
STS-60	Mid/Late-January	Discovery

Orbiter



OPF-3 high bay as seen from the south. The OPF-3 support area is on the right. The orbiter enters the building through the large sliding doors.
All photos supplied by the author

Within hours of landing at KSC (or returning to KSC aboard a Shuttle Carrier Aircraft) a Space Shuttle orbiter is towed to the Orbiter Processing Facility (OPF). NASA has three of these sophisticated hangars at KSC and it is here that the shuttle orbiters spend most of their time between missions. In early-July of 1992 *Keith Wilson* had the opportunity to visit OPF-3 and was able to see for himself the impressive scale of this facility and the work in progress.

BY KEITH T. WILSON
Lanarkshire, Scotland

OFP-3 History

Similar in configuration to the nearby OPF-1 and OPF-2, OPF-3 is used for orbiter post-flight de-servicing, testing, modifications and pre-flight processing. Originally it was named the Orbiter Modification and Refurbishment Facility (OMRF). It opened for business in 1987 and was used primarily for offline orbiter inspection and repair work and non-hazardous activities.

In 1989 NASA began upgrading the OMRF to full OPF status at a cost of $85 million and the facility was officially opened on 3 September 1991 in time to accept OV-103 Discovery following the STS-48 mission to begin processing for mission STS-42. Lockheed Space Operations performed the check-out of the entire facility. OV-102 Columbia was actually the first spacecraft to occupy OPF-3 when it was towed in for a fit check in the late summer of 1991.

Much of the equipment now installed in OPF-3 came from the Vandenberg Air Force Base in California as a result of NASA's decision to curtail Shuttle flights from the US west coast. Work platforms were shipped to Florida in pieces and were then reconstructed at KSC. Some of the ground support equipment is shared between all three OPF bays.

OPF-3 is the same size as its sister facilities. Its dimensions are: 60m long, 46m wide and 29m high. It is equipped with a 27 tonne bridge crane, work platforms which effectively surround the orbiter to provide personnel access, a main access bridge and two rolling bridges to provide access to various areas of the orbiter. Each of the rolling bridges supports two independent movable trucks with a personnel bucket at the bottom of vertically telescoping arms. The buckets are individually rotatable around a full circle. An emergency exhaust system in case of a hypergolic fuel spill and a fire protection system are included in the facility as well as an underfloor trench system containing electrical, electronic, communications instrumentation and control cabling.

Endeavour's lower left wing and deployed main landing gear.

Horizontally-handled payloads such as Spacelab are installed in the OPF whereas vertically-handled payloads are usually installed at the launch pad.

An adjacent 8000 square metre support area includes processing shops, logistic areas, flight hardware storage and administration/office space.

OPF-3, being the most recently constructed of the three processing facilities, has some unique improvements to the existing OPF-1 and OPF-2. A built-in computerized cooling system for the orbiter's environmental control life support system and new hydraulic pumpers that connect with the orbiter are included. OPF-3 has also been designed for easier flow of ground support equipment and its support area is also larger than its counterpart at OPF-1/2.

With three orbiter processing facilities now in operation Shuttle managers have more flexibility in planning processing timelines.

My Visit

During my visit to OPF-3, NASA's newest orbiter vehicle, OV-105 Endeavour, was undergoing processing for the STS-47/Spacelab J mission. Work in progress included preparations for in-

Former NASA Pilot Milton Thompson

An Appreciation

Former NASA research pilot Milton Thompson was one of the twelve pilots who flew the hypersonic X-15 rocket-powered research aircraft. He made 14 flights in the X-15 between October 1963 and August 1965, reaching a maximum speed of Mach 5.48. He was also the first man to fly the lifting bodies, wingless reentry vehicles that made an important contribution to the eventual design of the Space Shuttle.

BY ED HENGEVELD
The Netherlands

Thompson accepted an engineering job at NACA in 1956, working on the early X-airplanes. After two years, a slot became available in the pilot's office and Thompson was accepted. At that time, he felt that the glory days of the X-planes were over and that he had missed all the action. In the following years he realised that he had been wrong.

In 1962, Thompson was selected by the Air Force as the only civilian pilot for the X-20 Dyna Soar program. The X-20 was to have been the first spacecraft capable of a horizontal runway landing, but the programme was cancelled before construction of the first prototype.

Pilots in front of the No. 2 X-15 in 1965. From left: Joe Engle, Milt Thompson, Bob Rushworth, Paul Bikle (director of NASA's Flight Research Center), Pete Knight, Jack McKay and Bill Dana. *NASA*

"When Dyna Soar was can-

Processing Facility 3

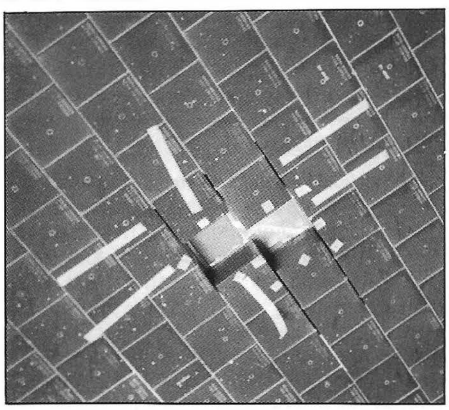
stallation of the Spacelab J module, functional tests of the OMS pods, leak and functional tests of the auxiliary power units and payload bay door inspections. At the time of my visit (7 July 1992) OV-102 Columbia was on-orbit nearing the end of the STS-50 mission; OV-104 Atlantis was located at Launch Pad 39B in preparation for the STS-46 flight and OV-103 Discovery was located in OPF-2 undergoing processing for the STS-53 mission.

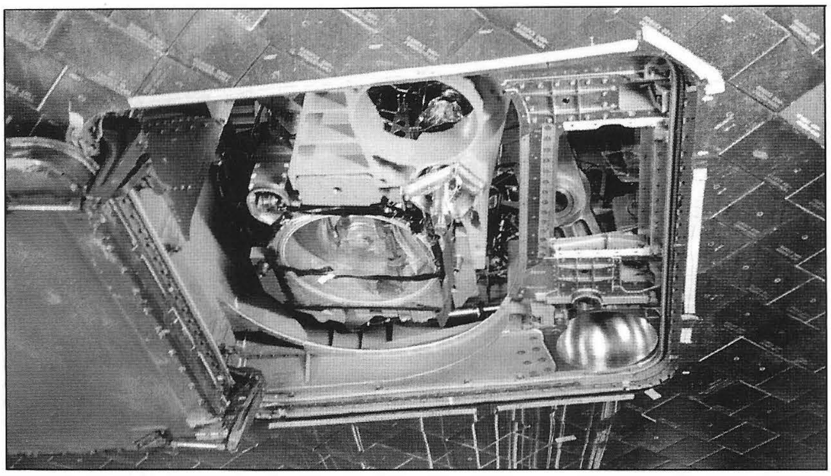
I entered OPF-3's high bay (where the orbiter is located) through the adjacent OPF support area. All employees and visitors are required to leave their identification cards on a wall rack just outside the high bay. This allows officials to know exactly who is in the bay at any given time. Entry to the high bay itself is through double doors which have the effect of blowing air outwards from the high bay thus lowering the chance of contaminating the high bay with dust. Employees are faced with a number of warning signs on entering OPF-3's high bay:

WHEN ENTERING WORK STANDS OR AROUND THE ORBITER YOU MUST-

1. Remove all personal items from upper pockets.
2. Remove or tape jewellery to the skin.
3. Tether all tools.
4. Tether eye glasses.

Close-up of the black heat-resistant tiles on undersurface of Endeavour showing area due for tile replacement following damage during the STS-49 mission.





Endeavour's right orbiter/ET aft attach fitting, liquid oxygen conduit and orbiter/ET umbilical door in open position.

Safety of personnel and flight hardware is of paramount importance in the processing facilities. A Foreign Object Damage/Debris (FOD) programme was initiated in 1989 to cut down on objects being left in or around flight hardware that could possibly damage hardware or injure personnel. Since the introduction of the FOD programme the weekly number of recorded discrepancies in the area of FOD has seen a dramatic reduction of 88%. FOD notices are present everywhere in the building.

A Close Look at Endeavour

Opposite the entrance to the high bay, and only a few metres away from the orbiter, is the OPF operations desk. A large electric sign above the desk indicated that Endeavour was 'powered'.

Endeavour itself was encapsulated in work platforms but I was given the opportunity to walk around and under the orbiter and was able to view various parts of the spacecraft including the main and nosewheel landing gear in the deployed position, the orbiter's nose, the wings and body flap, the main engine area, the orbiter/ET aft attach fitting with hatch open and extensive areas of Endeavour's black heat-resistant tiles. The tiles appeared in good condition following Endeavour's maiden flight on STS-49. Some had been repaired and replaced and a few were missing awaiting replacement tiles to be fitted.

As I moved around the building I noticed the main engine heat shields laid out on the OPF's pristine floor. The orbiter's main engines had been removed from the vehicle. Most of the engineers and technicians working on Endeavour were on the upper work platforms and only a few were to be seen at ground level.

Sixty seven days after my visit Endeavour was back in space on its second mission - STS-47. Days later the processing cycle started all over again.

Acknowledgments

The writer would like to thank Jennifer McCarter (NASA HQ), Kay Grinter, Lisa Malone and Manny Virata (NASA KSC) without whose assistance this article would not have been possible.

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celled, I still felt strongly that NASA should be looking at some means of flying back from orbit rather than come back in a capsule," Thompson said later.

He became project pilot for the lifting body programme and made the first flight in the wooden M2-F1 in 1963 and its metal successor M2-F2 in 1966. According to Thompson, "the lifting body program was my biggest contribution during that period. I had quite a bit to do with program development. It was very rewarding to pass on all this experience to the people who developed the Space Shuttle. The Space Shuttle benefitted greatly from information that came from the X-15, lifting body and Dyna Soar programs. I was in a good position to pass on that experience".

Less well-known was Thompson's involvement in a program called Paresev (for paraglider research vehicle). This unusual craft was built to study the feasibility of using a deployable kite-like glider wing as a means of landing a Gemini spacecraft on Earth after it had reentered the atmosphere. Paresev was flown from 1962 until 1964, when NASA abandoned the concept.

In 1975 he was appointed Dryden's Chief Engineer and later Associate Director (for technical matters) of the Dryden Flight Research Facility. He also served on NASA's Space Transportation System Technology Steering Committee. In that capacity he convinced Space Shuttle officials that the orbiter could land unpowered, eliminating the need for landing engines and thus increasing payload capability. That contribution earned him NASA's highest award, the Distinguished Service Medal.

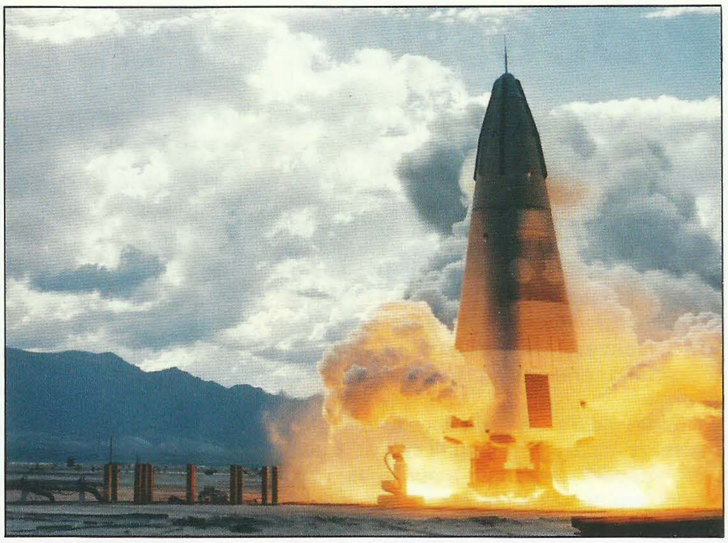
Thompson's involvement in efforts to preserve Dryden's history led to the publication in 1992 of his book "At the Edge of Space", detailing his role in the X-15 program. He died on August 6 at the age of 67 at his home in Lancaster, California. At the time of his death he was Chief Engineer at the NASA Dryden Flight Research Facility, a position he had held since 1975.

Milt Thompson is shown with the Paresev, used to test landing techniques for the Gemini program, 1962-1964. *NASA*

First Flights of the DC-X

In a manner similar to the Wright brother's first flights at Kittyhawk, North Carolina, history was made in a subtle way on August 18, 1993 with the first test launch of the DC-X SSRT (Single Stage Rocket Technology) testbed vehicle.

BY W. PAUL BLASE
Virginia, USA



Right: Lift-off for the initial hover test at White Sands Missile Range, NM on 18 August 1993.
Photo by George Baird, US Army, White Sands Missile Range, NM

Test Run and Official First Flight

In what was actually a "bunny hop" test run for the official "first flight", the DC-X lifted in a cloud of smoke from its launch pad, rose to 150 feet In the air, hovered steadily, translated 350 feet sideways, extended its four landing legs, and descended gently to the landing pad. The craft finished its flight by touching down at 1 foot per second, within six inches of the landing target. The entire flight lasted sixties seconds.

Only one minor problem marred the test run. Unburned hydrogen from the engines found its way under the lip of the DC-X's nose cone and ignited, scorching it. The nosecone was replaced, with a slight modification, and coated with fire retardant; an infrared camera was then installed inside the craft on the next flight to find the source of the leak.

The official first flight of the DC-X, with media and VIP's in attendance, occurred 24 days later on September 11. A virtual repeat of the "bunny hop" test, the craft again lifted from the pad and hovered, this time at 300 feet, translated sideways 350 feet, and landed safely. No damage to the craft was reported this time, in fact one witness to the event reported that the flight crew wanted to unofficially advance the test schedule and fly the craft again 4 days later, effectively demonstrating the craft's rapid turnaround capability.

DC-X

The DC-X (officially the SX-1, for Spaceplane Experimental) was constructed by McDonnell Douglas Space Systems Corporation for the US Ballistic Missile Defense Organization (BMDO) to demonstrate and test SSRT concepts. It is a 1/3 scale suborbital testbed which is designed to test and demonstrate various aspects of MDSSC's SSTO (Single Stage To Orbit) design, in preparation for the design and construction of a full-scale, orbital vehicle [1].

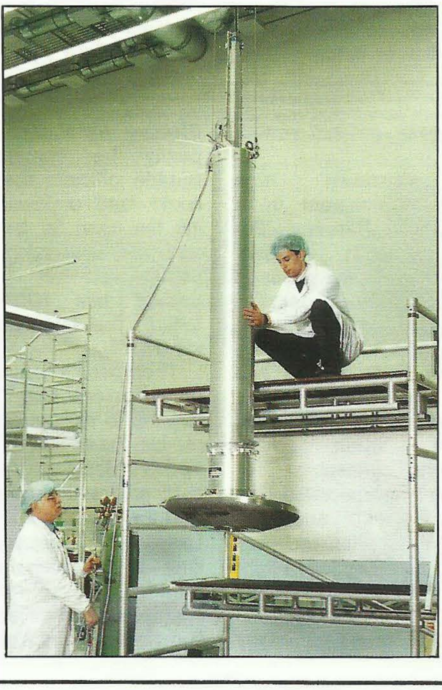
The DC-X stands 40 feet tall and is roughly cone shaped, with a circular nose blending into a square base 13 feet across. Set into each side of the base are four hydraulically powered manoeuvring flaps, similar to aircraft speed brakes, which are extended up to 30 degrees to control the vehicle during flight. In the bottom of the vehicle are the four extendable landing legs and the four Pratt & Whitney RL10A-5 engines. The engines burn liquid hydrogen and liquid oxygen, supply 13,500 lbs thrust each, and gimbal $\pm$ 8 degrees each. The RL10A-5 is a special version of the RL10A designed for a wide throttling range (30% to 100%) and sea-level operation. During hovering and landing, the vehicle is controlled by gimballing the engines and, secondarily, through differential throttling. The engines should last the duration of the test period without need for replacement. Although all tests call for a vertical landing on the landing gear, the craft's nosecone does contain a parachute, which can be deployed in case of emergency.

Built on a shoestring budget of $60 million in less than two years, the DC-X is an impressive demonstration of frugality and recycling. It utilises an F-15 fighter's inertial navigation system, a commercial Global Positioning System, accelerometers and other sensors from the F-18, and a flight-control system developed by Honeywell for airliners. The graphite-epoxy aeroshell was built by Scaled Composites

Landing Gear System

The Landing Gear System for the first flight model of the DC-X vehicle was developed and built by Deutsche Aerospace AG (Dasa/Munich) for McDonnell Douglas Aerospace.

Landing leg under laboratory test. *DASA*



A vertical landing is accomplished using retro-thrust from the four main engines, finally settling onto the Landing Gear System, which consists of four identical, retractable telescopic legs, designed to safely and gently absorb the remaining vertical velocity at engine cutoff while maintaining safe ground clearance for the engines. A sensor integrated into the Landing Gear System provides the signal for engine shutdown.

Two landing modes were considered in the design of the system:

- normal landing (landing with retro-thrust on a concrete landing pad)
- emergency landing (landing using a parachute on a sand surface)

The design of the Landing Gear System takes into consideration the maximum allowable delay and reactive forces, the various loading cases and the maximum permissable loads for the landing surface. The layout is restricted by the interior volume available for retraction and the required ground clearance. The extreme environmental conditions such as high vibration level and thermal requirements are dictated by the close proximity of the Landing Gear System to the engines and the cryogenic propellants in the tanks and feed systems as well as the partial reflection of engine exhaust during launch and landing.

Inc., the company founded by Burt Rutan of Voyager (the first flight to go non-stop round-the-world without refuelling) fame.

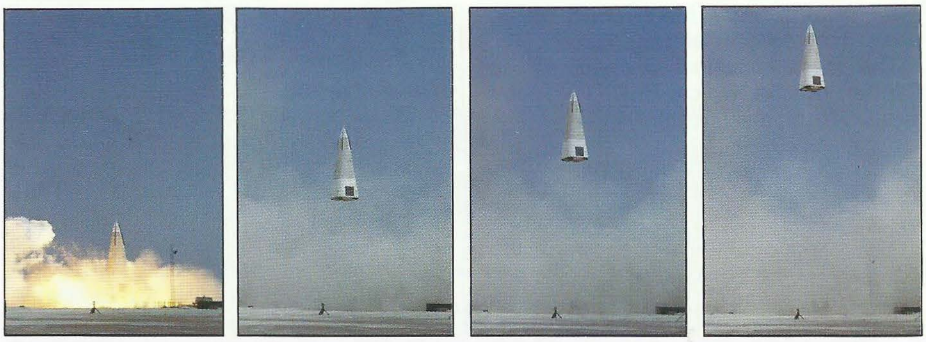
The DC-X was rolled out at MDSSC's Huntington Beach, California, plant on April 3. It, along with its portable launch system, was then transported to the White Sands Missile Range in New Mexico. In the period from May 20th to June 17th, the DC-X underwent a test series of nine engine firings and vehicle systems exercises, including two firings in one day with complete defuelling/vehicle servicing/refuelling between them. Between every test, the vehicle was serviced according to "aircraft-like processes and procedures".

In a demonstration of the DC-X's relative simplicity, the entire flight pad setup - comprising a trailer-housed Flight Operations Control Centre, the launch support pad, fuel handling facilities, and communications equipment - was packed up, trucked 50 miles to a different site, and reassembled prior to the August 18 test hop.

Future Programme

The full-sized Delta Clipper SSTO craft is to be a fully reusable launch vehicle, capable of carrying 20,000 pounds to Low Earth Orbit and returning safely to the launch site. The craft's designers and proponents intend the Delta Clipper to reduce launch costs dramatically through a combination of total reusability, reduced operating costs, greatly increased safety and reliability, and a rapid turn-around time (less than one week) between flights.

The Delta Clipper (also called the DC-1) is a conical craft, approximately 130 feet high and 30 feet across at the base, powered by 8 to 10 engines burning liquid hydrogen and liquid oxygen. The DC-1 will launch vertically from its launch pad, like any rocket. Following completion of its mission, the DC-1 will reenter the atmosphere nose first, slow to subsonic speeds through aerobraking, ignite its engines, rotate to a tail-first attitude, throttle up the engines, as-



The DC-X ascends to begin its series of flight tests, 11 September 1993. *McDonnell Douglas*

Flight Report, 11 September 1993

Following detailed evaluation of the initial DC-X hover test data (August 18, 1993) and a thorough vehicle and support system inspection, the DC-X took off from its launch stand at the WSMR SSRT site on September 11, 1993. The DC-X performed an automated systems check prior to engine start. It then autonomously determined engine readiness for the flight during the first three seconds after engine start. With a 'go-ahead' the vehicle then throttled up and at about 80 percent of rated thrust, lifted off.

Following takeoff the DC-X flew to approximately 300 feet above the ground, where it hovered for about 3 seconds and began its lateral translation manoeuvre. The DC-X then flew horizontally 350 feet to a point directly over the landing pad, where it again hovered for about 3 seconds prior to starting its landing phase. Throughout these manoeuvres the vehicle was gathering aerodynamic, stability, and control data concerning the low speed vertical and horizontal flight regime.

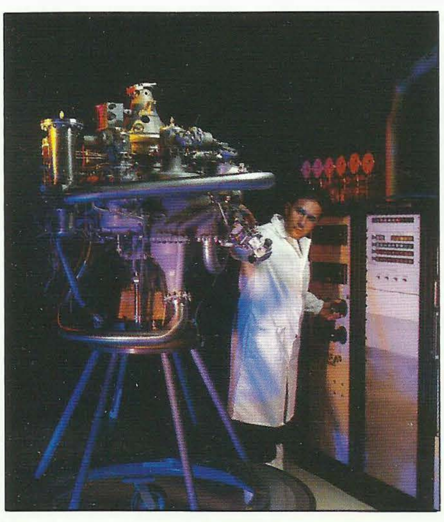
Once into its descent for landing phase, the vehicle lowered its landing gear and performed a powered, precise soft landing within 3.5 feet right and 1.5 feet short of the landing pad centre. With a 'weight-on-gear' indication the vehicle shut down its engines and began its self safing process in preparation for the small, six to seven person, post-flight recovery crew to arrive.

As with any aircraft the recovery crew performed its post-flight inspection and began cryogenic propellant off-load depressurisation. This initiated the DC-X turnaround process which readies the vehicle for another flight. During this entire mission, pre-flight through post-flight, data were being successfully gathered on the operation of the SSRT systems and subsystems as well as the entire DC-X system maintainability and supportability.

The Rocket Engine that Powers Delta Clipper

Four Pratt & Whitney liquid-oxygen and liquid-hydrogen fuelled RL10A-5 engines power the DC-X vehicle. The RL10A-5 is the latest in P&W's family of RL10 upper-stage rocket engines. The RL10, the world's first hydrogen-fuelled rocket engine, has been in service for 30 years. The RL10A-5, a derivative of the RL10A-3-3A and RL10A-4 models, has been modified for sea level operation with a new thrust chamber design. It also features a 30 to 100 percent variable throttling capability. The A-5 produces 14,560 pounds of thrust and 368 seconds specific impulse in vacuum.

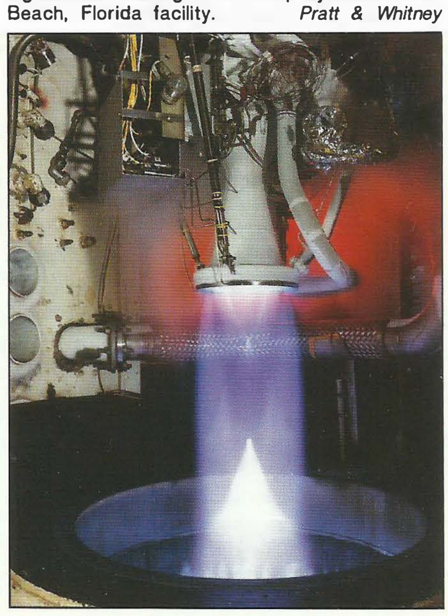
A Pratt & Whitney engineer inspects an RL10A-5 rocket engine being assembled at the company's West Palm Beach, Florida facility. *Pratt & Whitney*



P&W is evaluating several propulsion concepts for larger and full-scale Delta Clipper prototype vehicles currently being designed.

RL10 rocket engines have been in production since the early 1960s. The RL10A-3 models, in service since 1964, provide 16,500 pounds of thrust. In 1991, P&W introduced an increased thrust version, the RL10A-4, providing 20,800 pounds of thrust. To provide Centaur vehicles with additional mission flexibility, the company is currently qualifying an up-rated A-4 model at 22,300 pounds of thrust. Centaur vehicles combine with Atlas and Titan boosters on a variety of Earth orbital and interplanetary missions. The company is also evaluating further growth RL10 models producing more than 30,000 pounds of thrust for a single Centaur configuration.

The newest RL10 model, the RL10A-5, undergoing sea level testing at the company's West Palm Beach, Florida facility. *Pratt & Whitney*

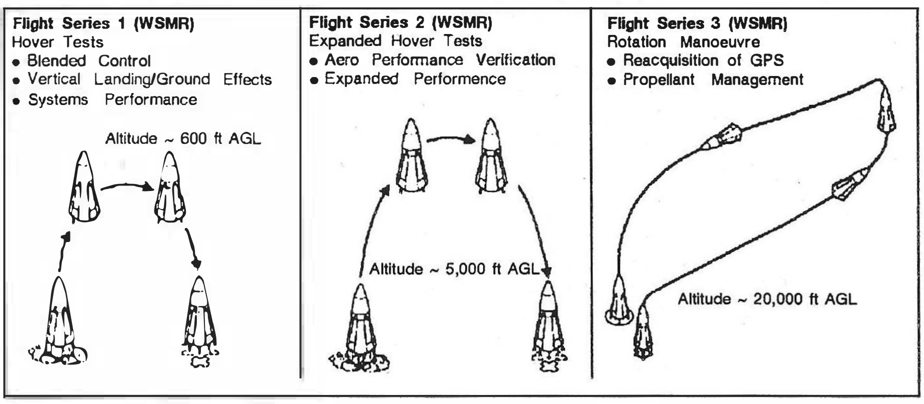


sume a stationary hover, and slowly lower itself to the landing pad.

The most important aspects of the Clipper design which BMDO intends the DC-X to test include:

(1) Atmospheric manoeuvring, hovering, and tail-first landing. In tests to come, MDSSC will take the craft consecutively higher, expanding the flight envelope with each flight, ultimately reaching 20,000 feet. The flights will explore the atmospheric manoeuvring characteristics of the Clipper's conical shape, which is a lifting body at high speeds, and prove the feasibility of the critical reentry rotation manoeuvre. In all of the flights, the DC-X will hover and land vertically on its landing gear.

(2) Operation with reduced ground support crew. The DC-X uses a highly automated control centre, manned by only three people: two for flight operations and one for ground operations and servicing.



The DC-X test programme is similar to an aircraft "flight envelope expansion" programme.

(3) Reusability and rapid turn-around. Ease of maintenance and rapid turn-around are critical to the Delta Clipper's promise of reduced launch costs. The next two flights in the test programme, currently scheduled for mid-October, will demonstrate this capability. The nominal target is a three-day turnaround between flights; MDSSC is confident that they can do significantly better.

The DC-X flight tests make up Phase II of a three phase programme. Phase I was a $12 million design and risk reduction competition, which explored several potential SSTO designs. Successful completion of the DC-X testing will form the basis for a go/no-go decision by the Department of Defense to develop a Phase III Advanced Technology Demonstrator. While still suborbital, this demonstrator would improve on the DC-X design and allow further expansion of the test envelope subsequent to the construction of an orbit-capable test vehicle.

Reference

1. W.P. Blase, "The First Reusable SSTO Spacecraft", **Spaceflight**, March 1993, p.90.

Single Stage Rocket Technology (SSRT)

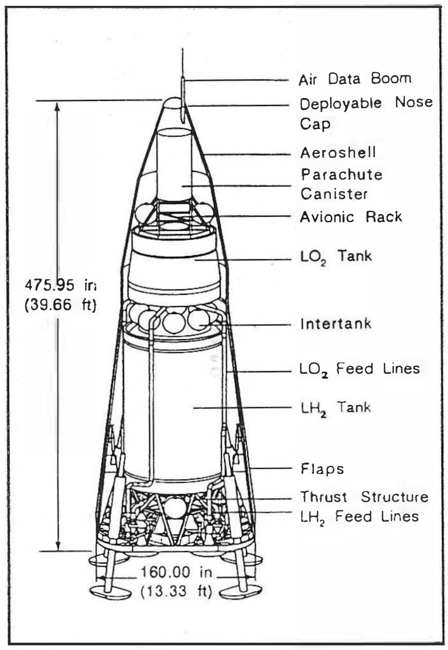
Background

On August 16, 1991 the Ballistic Missile Defense Organization (BMDO) selected McDonnell Douglas Aerospace in Huntington Beach, California for the Phase II Single Stage Rocket Technology (SSRT) programme. During Phase I of the programme four contractor teams evaluated different concepts for achieving single-stage-to-orbit and return operation. Based on the designs and as a result of a competitive proposal process, BMDO selected the vertical take-off/landing concept proposed by McDonnell Douglas.

DC-X Programme of Tests

Under the BMDO contract McDonnell Douglas and its teammates have designed, developed and assembled a totally reusable, autonomously-controlled flight vehicle, the DC-X, which uses liquid oxygen and liquid hydrogen, stands 40 feet tall, is approximately 13.5 feet across its base heat shield, and weighs 41,630 pounds at takeoff.

In June 1993 the DC-X team completed the cold flow and hot firing static tests at the NASA-JSC White Sands, NM, Test Facility. This series included mission-duration engine firings, propellant loading tests, verification of vehicle maintenance procedures, and ground and flight control operations.



DC-X layout. *McDonnell Douglas*

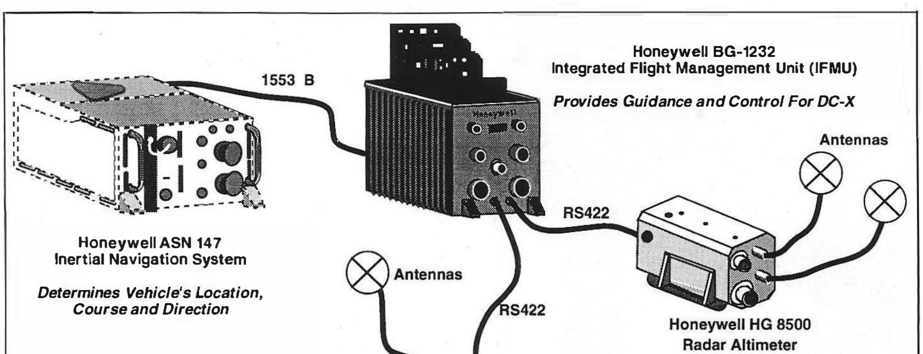
The flight test series is being conducted at the Space Harbor region of the White Sands, NM, Missile Range. Each flight series may contain multiple flights within a given series:

Flight Series 1 will include low-altitude hover tests designed to validate take-off, vehicle handling qualities, flight controls, verticle landing and overall system performance.

Flight Series 2 will include high-altitude hover tests designed to determine vehicle flight qualities at increased dynamic pressure. The tests will obtain more data on vehicle aerodynamic performance, simulate a vertical return-to-launch-site abort mode, and verify control performance in the presence of winds and ground effects.

Flight Series 3 will test the DC-X at higher vehicle dynamic pressure, examining combined aero/propulsion control and the rotation manoeuvre which moves the vehicle from nose-forward to base-forward flight.

Honeywell Space Systems Division in Clearwater, Florida provided the inertial navigation system, the Global Positioning System (GPS) receiver, the flight control computer and the radar altimeter for the DC-X vehicle. During the flight test, Honeywell's inertial navigation system updated by the GPS determined the vehicle's location, course and direction; the flight control computer processed the data and provide aerosurface and propulsion commands needed to maintain the desired flight path; and the radar altimeter accurately determined the vehicle's altitude, an important controlled landing requirement.



In the Ariane 5 programme Dornier is the contractor to CNES for the development and manufacturing of Speltra.

The new Ariane 5 launcher has six times the thrust of the most powerful Ariane 44L and is scheduled for launch in October 1996.

Speltra (Structure Porteuse Externe de Lancement Triple Ariane 5) is not only the outer skin of the Ariane 5 launch vehicle, but, as a support structure, it also accommodates a satellite and a second payload can be mounted on an adapter on top of Speltra's upper conical part.

Once the launch vehicle has reached the planned geostationary transfer orbit, a pyrotechnical separation system jettisons Speltra from the upper stage and the payload is released into its orbit.

The Dornier-led Satellites and Application Systems Division of Deutsche Aerospace AG (Dasa, Munich) has now delivered the first Speltra structure, the huge component requiring special transport from Friedrichshafen to Munich where it will undergo vibration testing.

A sandwich panel design was chosen for Speltra to comply with the exacting requirements for high strength and stiffness as well as acoustic and environmental protection demands. Two carbon-fibre reinforced (CFRP) layers, each 0.8 mm thick, are joined with an aluminium honeycomb forming the 30 mm thick skin of Speltra. Aluminium rings are used to join these panels - six each for cylinder and cone. The joints are bonded. In certain locations Speltra can sustain loads of up to 50 tons. It has a diameter of 5.40 metres, is seven metres high and weighs only 850 kg.

Dasa has already built a similar payload carrier assembly for Martin Marietta under the terms of the commercial Titan programme which was successfully flown when Mars Observer was launched September 1992.

The 90 million DM development contract for Dasa in Friedrichshafen covers the manufacture of three Speltras (two prototypes and one flight unit). The order is to be completed in May 1995 with the delivery of the flight unit, called MV 501. It is expected that the development programme will be expanded by a further flight unit (MV 502) directly after completion of the MV 501. Negotiations to this effect are already in an advanced stage. The following production phase will run until the year 2015 and provides for an annual output of six Speltras.

Dasa

Ariane 5's Major Non-French Contractor

Since the start of Ariane development in 1974, the Dasa Space Systems Group has been involved increasingly in this launcher programme. For the first time, it now assumes full responsibility for a complete stage in the development and manufacture of the new Ariane 5 launcher.

Ariane 5's upper stage ARES (Ariane Reignitable Expendable Stage) controls payloads and injection into the transfer orbit. The upper stage engine can be ignited several times.

The Dasa-developed SCA (Systeme de Controle et d'Attitude), housed in the Ariane 5 nose, performs the fine adjustment of the injection angle as well as the separation of the central and upper stages. In addition, SCA is responsible for the roll control of the entire launcher after booster separation and for attitude control of the upper stage and the payloads. A new feature in the Ariane programme is the disposal of the upper stage. It will burn up in the atmosphere after having fulfilled its task.

As well as the Speltra structure, Dasa furnishes the thrust chamber system for the Vulcain engine of the central stage and numerous other components. All thrust chamber system tests are performed on the Dasa test stand in Lampoldshausen. Development and qualification tests are planned to be concluded by the end of 1993.

Left: Speltra is lifted out of the integration fixture in which six cylindrical and conical panels are bonded to each other, connected with aluminium-alloy rings and provided with vent holes. *Centre:* The Speltra carbon-fibre structure viewed from inside. *Right:* The first Speltra model after painting. Clearly visible are the doors allowing access to the payload, as well as the vent holes on the upper cylinder edge. Speltra is 7 metres high and has a diameter of 5.4 metres.
Photos courtesy of Deutsche Aerospace

Some Details on Project Zenith (1957 Onwards)

Glasnost and the declassification of Soviet Ministry of Defence archives have shed some new light on early American - Soviet space rivalry and the early days of the Soviet photoreconnaissance programme [1].

What has been termed in the west as the 'first-generation' of photoreconnaissance satellites was known in the USSR as project Zenith. The contract to design Zenith was given to Sergey Korolyov and his design bureau (OKB #1) as far back as 1957, confirming the early military orientation of Soviet rocketry.

Interestingly, the American programme for photoreconnaissance from space started at about the same time, but it achieved orbit (1959) and flight success (1960) sooner. This was project Corona, known publicly as the Discoverer programme [2]. But unlike the early American programme, the early Soviet design was quite similar to the man-in-space programme, Zenith sharing many features in common with the Vostok spaceship.

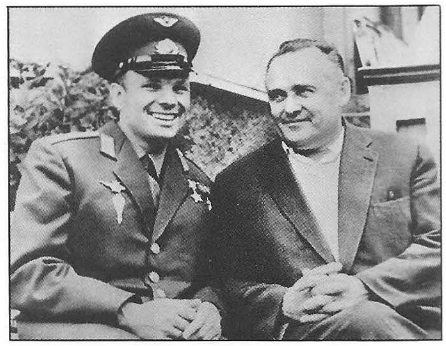
The Zenith design was completed in mid-1961, the first attempt to launch Zenith being made at the very end of that year. It failed, Zenith not reaching orbit due to a fault in the launcher's third stage. The next attempt was the first Zenith success: it took place on 26 April 1962. The satellite, subsequently designated Cosmos 4, was recovered after three days, but there were serious teething troubles with the attitude control system and with the camera system. The first normal flight, identified as Cosmos 7, was in July 1962 which was faultless. Gradually, missions were extended to eight days duration. Of the first twenty Cosmos satellites, ten belonged to the Zenith programme. Finally, the programme was declared operational eighteen months later in early 1964 [3].

Zenith carried four cameras. The swath was 180 km wide. The cameras could be turned for oblique shots of the Earth's surface. The aim was to cover an area of 10 million sq km, the equivalent of the surface area of the United States, in the course of a mission. Each camera could take up to 1,500 frames. Zenith's resolution was sufficient to identify cars in a car park. In 1963, responsibility for the photoreconnaissance programme was transferred to a branch of the #1 OKB, where it remained ever since.

References

1. Radio Moscow, *Science and Engineering*, 6 September 1993, see also *Aviatsia I Kosmonautika*, March 1993, 41-2.
2. William E. Burrows, *Deep Black*, Bantam, London & New York, 1988.
3. Details of its subsequent evolution may be found in Phillip S. Clark, Aspects of the Soviet Photoreconnaissance Satellite Programme, ***JBIS***, Vol **36**, pp.169-184, 1983. My thanks are due to Phillip Clark for his comments in the preparation of this report.

Brian Harvey



Yuri Gagarin and Sergey Korolyov.

Gagarin's Spaceship Originated as Spy Satellite

The Vostok piloted by Yuri Gagarin on April 12, 1961 was originally designed as an *unmanned* spy satellite. Based on this concept chief designer Sergey Korolyov (1906-1966) developed a version to accommodate a human being. This writes Mikhail Rebrov, scientific observer of the Russian army newspaper *Red Star*.

Korolyov was at first handicapped by the fact that he could only operate within the military-industrial organisation of the time. During the second world war he built the famous *Katyusha* multiple rocket launcher, dubbed Stalin Organ by the Nazis. He also designed the first intercontinental missile, which made its maiden flight in 1960 and could deliver an atomic warhead to Europe and the United States. This rocket, the R-7 or *Semyorka* (Little Seven) was used a year later to put Sputnik-1 in orbit. The project actually originated on the basis of the personal enthusiasm of Korolyov and his engineers. It was rather tolerated than supported by the Supreme Soviet.

Only after Nikita Khrushchev had been confronted with the effect of the ensuing world-wide publicity did he encourage Korolyov to strive for similar successes. In this way, within four weeks, Sputnik-2 was created and launched with the dog Laika. At that time it was not possible to bring the spacecraft safely back to Earth.

The surprised Americans reacted with the statement: "Who controls space, controls the Earth", writes Rebrov. That view also appealed to the Russians. They immediately started with the design of a spacecraft to take detailed photographs of the Earth's surface. The craft was equipped with a spherical capsule of 2.3 metres diameter, which housed a large camera with a telephoto lens to be brought back to Earth with the film. Under the neutral *Kosmos* flag hundreds of those satellites were launched to return to Earth within a few weeks.

Because the parachute landing of the sphere was rather hard, Korolyov thought of a solution which was rather uncomfortable but safer for the cosmonaut inside: at a height of 4000 metres the cosmonaut would eject to land as a normal parachutist. During his research into the once very secret KGB archives, Rebrov came across an original design for a manned rocket by Korolyov, which was probably done in 1944. But the circumstances prompted him to use what was available from military space designs.

Peter Smolders

Correspondence

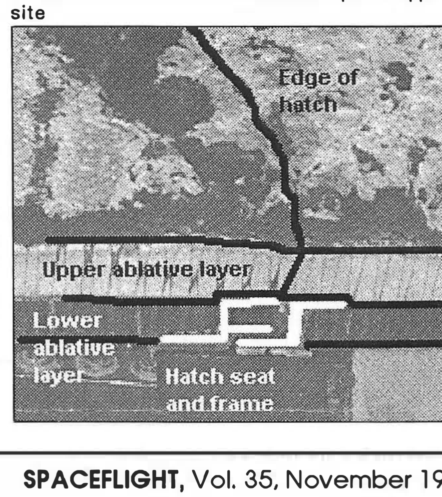
Re-Use of Gemini 2

Sir, Thank you for printing Scott Hedrick's letter (***Spaceflight***, July 1993, p.237) concerning the whereabouts of Gemini 2. Coincidentally, I was in Florida a few weeks after receiving that issue. I visited the Air Force Space Museum as part of the Kennedy Space Center's Blue Tour, and saw and photographed the spacecraft. However, I have interpreted the heat shield quite differently than Mr Hedrick - the MOL hatch does exist.

The enclosed photograph shows the upper right corner of the cutout shown in Mr Hedrick's photo. The heat shield sectioning was done routinely after each mission, so that engineers could examine the effects of reentry. Some shields were split in half, some had small cores drilled out in various locations, and some had in-between sized areas removed. On Gemini 2, the top straight edge of the section was cut through the centre of the MOL hatch. In my photograph, just to the left of the red honeycomb block, can be seen the two metal angles of the edge of the hatch and its seat in the lower (black) honeycomb layer, as well as the slightly diagonal edge cut through the upper (white) layer of the ablative honeycomb. The red honeycomb blocks form a roughly octagonal support ring around the hatch cutout. In Mr Hedrick's photo, the semi-circular black region above the straight edge of the sectioned area is the edge of the hatch.

The edge of the hatch is cut diagonally

Hatch location on heat shield. See photo opposite



Moscow's International Aerospace Show

31 August to 5 September 1993

Following the undoubted success of 'Mosaeroshow 92' held at the Zhukovsky Gromov Flight Test Research Centre some 35 kilometres from Moscow (and falsely known in the west until recently as Ramenskoye), the 1993 show was spread over three widely dispersed sites in the Moscow area, including Zhukovsky.

Forming part of the historic aircraft exhibition at Khodinka, Russia's oldest airfield, in central Moscow was the Sub-Orbital Kosmolyot, used for shuttle development flights, described as BOR-4, and carrying Cosmos flight numbers 1374, 1445, 1517 and 1614. The dates for the first three flights were 03-06-82 (1374), 15-03-83 (1445) and 27-12-83 (1517. Also at Khodinka were around 60 former Soviet military aircraft, many of which form part of a permanent museum there.

The main space related items and trade stands were situated at the Krasnaya Presnya Expocentre, where the three pavilions housed exhibitors from the CIS and abroad, with the collaborative nature of today's space industry well represented, though the hardware was limited to a number of propulsion units such as

The BOR-4 model at the Khodhinka site.

the RD-170, situated outside in the plaza, together with a MiG-29 and a Moscow Police Bell 206L Longranger helicopter. Whilst of great interest, the lack of dual language information, especially in the captioning of models and photographs, reduced the impact of much of what was on show.

The airfield at Zhukovsky, which housed the main static and flying displays, has an impressive 18,000 ft runway (the largest in Europe) and 494 acres of paved surface, some of which was used to good effect to show off the same Buran shuttle and Myasishchev VM-T Atlant that were present last year (***Spaceflight***, November 1992, p.353). The Atlant, which is a conversion of the Mya-4 'Bison', was carrying a smaller tank on top this year, much shorter than the Energiya rocket fuel tank, with the rear end pointed instead of being rounded. Sadly, it stayed firmly on the ground this year, unlike in 1992 when it made an impressive feature in the flying display. Zhukovsky is also the home of a number of satellite tracking aircraft, notably of the Ilyushin Il-76 and Il-86 variety, whilst the Myasishchev ramp contained a reduced scale Buran, though a close examination of the latter proved difficult.

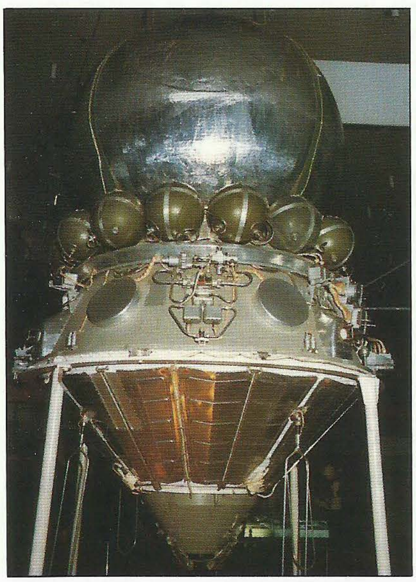
The next Mosaeroshow will not be held until 1995, mainly due to a potential clash with the well-established Farnborough show, when it is expected that all the exhibits will be displayed at Zhukovsky, the three widely dispersed sites being extremely inconvenient given the rapid increase in vehicular traffic in the Moscow area, and the lack of a satisfactory infrastructure to contain it. Whilst the Memorial Museum of Space, beneath the 295 ft monument to commemorate Soviet space exploration, still continued in use, the Cosmos pavilion, one of the major pavilions amongst the 80 large pavilions on this site, has been emptied of almost all of its historic contents and now serves as a saleroom for imported secondhand western cars of the expensive variety. The Vostok rocket booster still remains in front of the pavilion, in company with Tupolev TU-154 and Yak-42 airliners, the latter now sponsored by SEGA and used to demonstrate computer games inside.

As this is being written the situation in Russia continues to be volatile, but hopefully for the sake of the people, things will improve, though my overriding impression is of a nation that, in its desire to adopt western ways, has sadly rejected the triumphs of its own past along with the more obvious failures.

Trevor Hall

The RD-170 propulsion unit exhibited at the Expocentre Exhibition Complex.

The Vostok spaceship. *Peter Smolders*



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to form a plug that is forced into place by the shock waves that forms on the heat shield during reentry. This is the same effect as the plug type doors used on airliners, except that the pressure on the airliner is from the inside.

The centre of pressure on the heat shield is shown in Mr Hedrick's photo by the converging rays toward the bottom of the heat shield. Note that the hatch is positioned opposite that point, to lessen the stresses on it. This placement also placed the hatch in between the ejection seats inside. The console between the ejection seats would need to be relocated so that the hatch could be used. It would have been a very tight squeeze even in a shirtsleeve environment, with the exiting crew member's shoulders against the attitude controller on the bottom and the upper console on the top.

The hatch was obviously not func-

A close-up of the part of the heat shield where the hatch may be identified.

tional, as the pressure shell of the spacecraft has not been cut out. The hatch was apparently used to test the effects of reentry heat and pressure on the cut through the ablative material. Judging from the sectioned area, the test was quite successful. I could not detect any difference in ablation at the junction of the hatch and the heat shield.

In addition to the Kennedy Space Center Spaceport USA, there is also the Space Camp Florida/Astronaut Hall of Fame, just a few miles before KSC. The Hall of Fame exhibit has a large collection of spacecraft, astronaut gear and mementos. The exhibits include the Sigma 7 Mercury spacecraft, a 1/2 section Mercury heat shield, various space suits including Gus Grissom's Mercury suit, a Gemini mockup and other exhibits.

Two hands-on exhibits were:

1. Sitting in a Mercury mockup (No wonder there was a 5'-11" height limitation. I am 6 feet and I definitely did not fit comfortably!) and
2. Wearing a variety of Mercury, Gemini and Apollo space suit helmets.

PETER O. JOHNSON
New Hampshire, USA

SF and Promoting Space

Sir, I was interested to read the various comments concerning my letter about new SF drama on the BBC in the July issue of ***Spaceflight***. Having reviewed the replies, I think I should have been slightly more specific in my remarks.

Science Fiction might be held to cover any form of speculation about possible 'futures'. However, from the viewpoint of membership of the BIS, we are interested in a certain 'group' of futures, portraying, as with the 'The Shape of Things To Come', human expansion into space in a favourable light.

There have been recurrent rumours about the televising of 'Dan Dare', which would seem to fit the bill regarding the general story-line but nothing definite has emerged.

The letter from Mr Irvine, outlining the differences between the special effects available to film-makers and those available to producers of television drama, prompts two responses. The first of these is to wonder how desirable special effects are. Although the appearance of realistic scenes - planetary landscapes, stellar backgrounds, fleets of spaceships, etc. - can add substantially to the effect of an SF production, there is also a sense in which they can detract, if the film or TV production concentrates so much on 'spectacle' that anything of a deeper intellectual or philosophical nature is ignored. Sir Fred Hoyle's serial 'A for Andromeda' and the TV version of 'Quatermass and the Pit' had access only to the most limited (by present standards) special effects, and so had to rely on an effective 'thought-provoking' scrip. I actually found the use of black-and-white photography adding a certain 'documentary' feel to the productions.

The second response is to point out that, just as micro (and, increasingly, pocket) computers now run programs that once would 'fit' only main-frames, the special effects currently available on the 'big screen' may become available to TV producers. In which case, we need to try and exert an influence over the general type of production. The most recent film to depend heavily on special effects was Jurassic Park; a number of the reviews considered the film as a warning of the dangers of technology, not the sort of message one would want to see popularised.

I have news of the forthcoming revival of Hammer films and the production of new 'editions' of certain of their films, including one or more of the 'Quatermass' film versions. Comparing the new and original versions might well provide useful data concerning the greater availability of special effects and their influence on the 'intellectual level' of the films in which they are employed.

P.W. DAVEY
Dorset, UK

2001

Sir, I fear there is a small error in your notice of *Odyssey: the Authorised Biography of Arthur C. Clarke* by Neil McAleer in the August issue.

Clarke did not win an Academy Award (Oscar) for the film *2001*. The film was nominated in four categories: best film script (by Clarke and the producer/director, Stanley Kubrick), direction and special effects, but won only the special effects award. Ironically, a special Oscar was awarded the same year for the very stiff and unconvincing ape make-up in *Planet of the Apes*, while the utterly convincing primitive man make-up in *2001* was ignored, perhaps because it looked so authentic that people thought that the actors were *real* apes. Just goes to show it is possible to be too good!

RAY WARD
Sheffield, UK

Terraforming

Sir, The answer to Dr Vincent's important question is yes. It is right for us to modify another planet for our own use.

Her concern about not being able to study a "virgin Mars" once terraforming begins is not entirely valid. The completion of any terraforming plan would inevitably require the very data she is fearful of losing. Also, the implementation of such a design is not likely for many decades, if not centuries. If planetology continues to improve at even a fraction of its current rate, we have ample time to make a thorough study.

Her moral arguments are no more substantial. The schemes that have damaged our ecosystem were conceived by people with little knowledge or concern of ecological matters. That need not be the case on Mars for two reasons. First, the ecosystem on Mars is likely to be limited to a few microscopic fossils of creatures that died out long before our ancestors emerged from the water. Or perhaps there is nothing at all. Either way, there is no ecosystem for us to protect. Second, we can learn from our mistakes. It is not surprising that our first, uncoordinated attempts at modifying a planet resulted in errors. Some careful consideration of those errors should make future attempts considerably more successful.

Further philosophical questions relate to our obligations to our destiny as a species. Much of the original vision of the space age can be found in the phrase "The human adventure is just beginning". The meaning is clear. Though we might consider our East African origins to be the distant past, our ancestors will eventually regard their Earthly origins to be in their distant past. Of course, this assumption requires that we retain the urge to expand and grow which we share with all our related species. This urge sent us across deserts and oceans to find new lands. Are we as justified in searching for new lands in space?

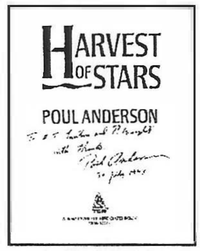
As a parallel, think of a palm tree and a rock on separate islands. The tree drops into the sea a coconut which floats to the other island and germinates beside the rock. Eventually the roots of the new tree split the rock. If we were to apply the Dr Vincent's morals to palm trees, would the palm tree be right to set its coconuts adrift? Is it right for the new tree to split the rock? Should we care about the welfare of the rock? Reason suggests that the good of the palm trees outweighs that of inanimate objects such as rocks.

Our hominid family separated from the apes about twelve million years ago, which means that we are still young in evolutionary terms. When we have aged another twelve million years, where will we be? Spread out across the Milky Way, with each colony developing a distinct human species and communicating with its distant kin? Or will we have put a stop to our old desire to grow, develop and explore for fear of repeating ancient mistakes?

HOWARD GLEN
Edmonton, Canada

'Harvest of Stars'

Sir, I enclose a photocopy of the signed front page with acknowledgements to myself and Penny Wright from Poul Anderson author of *Harvest of Stars*. It is his latest novel.



Much of the book is based on our paper "Searching for Other Worlds" published in the ***JBIS***, August 1991, pp.401-404. Anderson wrote to us in September 1991 - he did not waste any time in contacting us and a regular correspondence started.

The book has now been published in the US and is expected to be a best seller. Anderson is one of the top ten US SF writers and in due course *Harvest of Stars* will be published by someone in the UK. Presently it is in hardback but there will also be softback printings. The hardback is 400 pages - a long novel.

These events also show that ***JBIS*** goes far and wide and the extent to which it is valued and utilised.

ANTHONY T. LAWTON
West Sussex, UK

Delta Clipper Assessment

Sir, Concerning my letter in ***Spaceflight***, September 1993, p.321:

1. A confusing error was edited in: please replace 'A rescue mission is perhaps a possibility' by 'A rescue of this mission may be as follows: (DCE description as in my letter)'.
2. By now, we have more precise mass data on DCE, resulting in 7.1 t of payload, at 478.5 t lift-off.

Prof Dr-Ing H.O. RUPPE
Munich, Germany

Competition Winner

Sir, I was very happy to be awarded the video-tape "STS-49 Mission Highlights" in the 'Space Shuttle' Competition.

My job is that of a cameraman and I am deeply interested in astronautics, so the video-tape was a very valuable addition to my video collection of space documentaries! One of my great wishes is to one day become a cameraman for a space agency. Let us hope.

S. FERIER
Belgium

Sub-Stellar Homesick Blues

Sir, I would like to add a few comments to the search for space songs which has been conducted through the Correspondence pages of ***Spaceflight*** in recent issues. A leisurely trawl through the "Guinness Book of British Hit Singles" [1] has uncovered a list of records which - in name at least - appear to be less celebrated examples of the genre:

Chart Entry Date	Artist	Song Title	WoC	PP
13/04/61	Kokomo	Asia Minor	7	35
19/02/69	Don Patridge	Breakfast on Pluto	7	26
17/01/70	Derrick Morgan	Moon Hop	1	49
27/05/72	Kinks	Supersonic Rocket Ship	8	16
27/07/74	Mud	Rocket	9	6
11/02/78	Biddu	Journey to the Moon	1	41
13/05/78	Earth Wind & Fire	Jupiter	5	41
04/11/78	Brothers Johnson	Ride-O-Rocket	4	50
25/11/78	Rezillos	Destination Venus	4	43
12/05/79	Judas Priest	Evening Star	4	53
16/06/79	Slick	Space Bass	10	16
17/11/79	Atmosfear	Dancing in Outer Space	7	46
09/02/80	Rocky Sharpe and the Replays	Martian Hop	4	55
06/12/80	Bow Wow Wow	I Want My Baby on Mars*	6	58
14/11/81	Level 42	Starchild	4	47
12/06/82	A Flock of Seagulls	Space Age Love Song	6	34
21/02/87	Bob Geldof	Love Like a Rocket	3	61
21/11/87	Hooters	Satellite	9	22
11/02/89	Def Leppard	Rocket	7	15
05/08/89	Dogs D'Amour	Satellite Kid	3	26
29/09/90	Runrig	Satellite Flood*	2	49
08/06/91	New Model Army	Space	2	39
03/08/91	Five Thirty	Supernova	.1	75
11/01/92	Lush	Astronaut*	2	35
01/02/92	Only Ones	Another Girl-Another Planet	2	57
18/07/92	Wedding Present	Flying Saucer	1	22
08/08/92	Acen	Trip II the Moon	4	38
14/11/92	Wedding Present	The Queen of Outer Space	1	23
21/11/92	Prodigy	Out of Space	6	5

WoC Weeks on Chart
PP Peak Position
* Denotes EP track

In identifying these as "space songs" I should sound a note of caution, as I must confess that most of these songs are new to me. Of course, relying upon song titles alone is a dangerous business and can easily lead one up the wrong path. A recent interview with David Bowie has provided a prime illustration of this fact. His 1984 song "Loving the Alien" has often been interpreted as being about space, but the artist himself goes out of his way to refute notion: "This song was very confusing to a lot of people. I think it was basically taken to be another sort of space song. But in fact what I was trying to do was set up some line of thought that surrounded the possibility of harmony between Islam and Christian peoples. Little did I know one day I'd marry a Muslim." [2].

Several songs which I can, however, vouch for include: "Rocket's Tail" by Kate Bush and "Space Odyssey" by the Byrd's, which is a musical interpretation of Arthur C. Clarke's legendary short story, the Sentinel. The Rocket Man himself, Elton John, has also made several other less memorable trips into space in the form of "I've Seen The Saucers" from his 1974 album "Caribou" and "Satellite" which can be found on 1985's "Ice On Fire".

DARREN L. BURNHAM
Oxford, UK

References

1. Paul Gambaccini, Tim Rice and Jonathan Rice, "The Guinness Book of British Hit Singles", 9th Edition, Guinness Publishing, 1992.
2. Interview with David Bowie, MTV Europe, transmitted 5/8/93.

Australian Space Music

Sir, Further to the correspondence in recent months regarding space music, I thought that readers would be interested to know that Australia, too, has produced space-related songs and music.

In 1969, country and western singer Reg Lindsay commemorated the Apollo 11 Moon landing with his song "Armstrong". The Skylab crashdown in Western Australia in 1979 produced two musical mementos, "Skylab Fragment" by the bush band Captain Australian and His Mate Downunder, and "Balladonia Nights", a Top 40 hit by a popular group whose name currently escapes me. The launch of Australia's first Aussat (now Optus) communicaitons satellite also inspired two pieces of music, "Uplink" and "Adrift", by Tony Ansell.

KERRIE DOUGHERTY FBIS
Curator, Space Technology
Powerhouse Museum
NSW, Australia

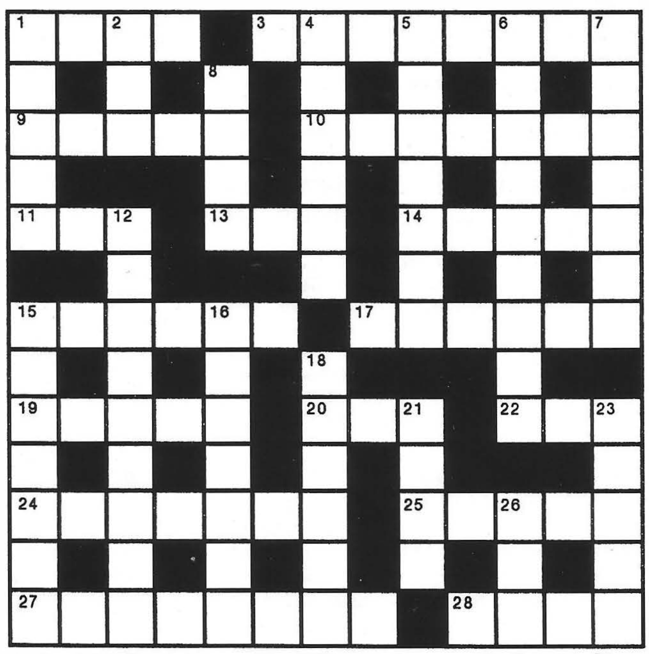
Spaceflight Crossword

No. 3

ACROSS
1 Orbiting companion of the Earth
3 'Beach Spa' hotel in shuttle orbiter ?
9 Number of main engines in shuttle orbiter
10 Mountainous communications satellite
11 Colour of the stone that first put the US in space ?
13 Space trajectory for a lion ?
14 Last part of US rocket that failed to be first in space
15 Open ——— for a spell of anti-gravity perhaps ?
17 Light eats
19 Scrub
20 Type
22 US space plan
24 Star classification for Venus or Mercury after sunset
25 Hairy heavenly body once taken as a bad omen
27 Small hand-telescope
28 Astronaut team

DOWN
1 Power-driven propulsion device
2 Hand-operated propulsion device
4 Space booster or nuclear particle
5 Freezing mixture
6 European astrometry satellite
7 Apart from
8 Device to prevent passage of gas in 1 Down
12 OV-103
15 All ——— go for launch !
16 Warlike reference to Mars
18 Retainers of EVA hatch particularly when open
21 Telescope on Hawaii
23 Tethered (2,3)
26 Space station

Solution will appear in the December issue.



Solution to Crossword No.2. **ACROSS:** 5. Buran; 8. Spaceman; 9. Bytes; 10. Reentry; 11. Oscar; 13. OTS; 15. Marecs; 17. Tested; 18. cps; 20. Reach; 24. Antenna; 25. Slope; 26. Meteosat; 27. Anode. **DOWN:** 1. Astra; 2. Wanes; 3. Delta; 4. Salyut; 6. Ulysses; 7. Averages; 12. Magellan; 13. OSC; 14. STS; 16. Escaped; 19. Planet; 21. Ether; 22. In use; 23. Hasty.

World Federation and Interstellar Travel

Sir, Dr Ian Crawford has chosen a most unfortunate example for his case that world federalism can boldly go where competition between nation-states cannot [1]. For the Apollo project is in fact the quintessential example of just such a competition.

Freeman Dyson has gone so far as to say:

> The success of Apollo was mainly due to the fact that the project was conceived and honestly presented to the public as an international sporting event and not as a contribution to science [2].

In his famous State of the Union message on 25 May 1961, President Kennedy called upon the United States to embark upon the lunar enterprise in the following ringing terms:

> If we are to win the battle that is going on around the world between freedom and tyranny, if we are to win the battle for men's minds, the dramatic achievements in space which occurred in recent weeks should have made clear to us all, as did the Sputnik in 1957, the impact of this adventure on the minds of men everywhere who are attempting to make a determination of which road they should take [3].

It therefore cannot be seriously doubted that Apollo was a child of the Cold War: that the first human landings on another world were made possible *not only* by the political unification of the United States in 1787, *but also* by the deadly rivalry between the new nation-state thus created and the Soviet Union.

But I wonder if I can guess at what Dr Crawford is trying to tell us? He argues that the raising of the largest unit of political organisation from the continental to the planetary scale would be the *logical conclusion* of the process of federalism [4]. I can find nothing in his article about raising political organisation to the *interplanetary* scale. And yet an interplanetary civilisation is obviously a prerequisite for interstellar travel.

Does this mean that the first starships to be launched to Alpha Centauri will be driven by the sublimation of a deadly cold-war competition between the rival world governments of the Earth and of Mars?

STEPHEN ASHWORTH FBIS
Oxford, UK

References

1. **Spaceflight**, September 1993, p.324.
2. Freeman Dyson, *From Eros to Gaia*, Penguin Books, 1993, p.52 (from an essay written in 1988).
3. Quoted in R.S. Lewis, *From Vinland to Mars*, New York: Quadrangle Books, 1976, paperback edition 1978, pp.153-4.
4. I.A. Crawford, **Spaceflight**, July 1993, see Conclusion on p.252.

Dr Ian Crawford replies:

Stephen Ashworth is certainly correct when he states that the Apollo programme was born out of the cold war competition between the United States and the Soviet Union. This is a matter of historical record, and I certainly did not mean to imply otherwise. My point was to show that American federation was a political precondition to all that the US has accomplished as a superpower, including its space programme. However, I claimed only that the continental federation was a *necessary* precondition, not that it was *sufficient*. Given that, in the fullness of time, federation provided the resource base which made Apollo *possible*, it of course remains true that such a project could never have been realised without strong political motivation.

As regards world federalism, I argued that this may be *necessary* in order to provide the resources and the political stability needed for the large-scale development and colonisation of the Solar System. I am well aware that it would not, in itself, be *sufficient*, and that it would still be necessary for such a project to win political support. Given that the old nationalistic driving force, which motivated Kennedy and others, would no longer exist, the force of Ashworth's criticism depends on the likelihood of finding other motivations which may seem equally compelling to the operators of the new political machinery. As argued in Part 2 of my article, I believe that, given a sufficient resource base, there do exist powerful motivations for space developments other than the international competition that has driven them to-date.

Finally, let me address the point about interplanetary government. I certainly agree that an interplanetary civilisation will be a prerequisite to interstellar travel, and in fact stated so explicitly in the Introduction to Part 1. Once a significant interplanetary society starts to appear (i.e. when colonies and outposts begin to become self-supporting), the question of appropriate political institutions will naturally arise, and I believe that the federal concept is capable of being extended to this scale. The essence of federalism is that political decisions are taken at the most appropriate level (something that in today's European context is known as 'subsidiarity', but which was in fact pioneered in America two centuries ago). Thus, in a fèderal Solar System, local decisions would still be taken at local level, national decisions at national level, planetary decisions at planetary level (something so conspicuously lacking in today's world), and Solar System decisions, presumably including those relevant to interstellar travel, at Solar System level. I suggest that interstellar exploration could be organised within such a framework, and emphatically do *not* believe that belligerent interplanetary competition would be either necessary or desirable.

First Manned Space Flight

Sir, The letter of A. Fellenberg (**Spaceflight**, October 1993, p.349) regarding an earlier manned space flight than that of Gagarin reminded me of a magazine article a number of years ago in which a claim is made that at least six other manned flights were made all of which failed.

The list of supposed flights is:

1. In February 1960 Terentiy Shiborin was launched in a Vostok from Kasputin. Signals were apparently picked up in Turin and Hawaii and suddenly ceased.
2. On 11 October 1960 Piotr Dolgov was launched and signals picked up in Italy, Turkey, England and Japan. The signals ceased after 30 minutes.
3. On 28 November 1960 signals were received in Turin by, apparently, another manned mission.
4. At 9:55 pm on 21 February 1961 Turin announced another space shot which apparently Jodrell Bank confirmed. Conversation was heard which lapsed into sounds of heartbeats which ceased 38 minutes after launch.
5. On 17 May 1961, from a base near the Arab Sea, Turin picked up signals from two cosmonauts, a man and a woman, which lasted for a week and then stopped.
6. On 8 November 1962 Alexis Belokonev was launched and was not heard of after 12 November.

All of these reports are apparently from a "respected" group of Italian scientists based at a tracking station near Turin.

W.E. DEWERSON
BIS Member, Essex, UK

Sir, I read with interest Mr Fellenberg's speculative letter (**Spaceflight**, October 1993, p.349) on a Vostok flight on 21 December 1960, and would like to correct several points raised. The failed Vostok capsule was Korlab Sputnik 4A, the flight of which was to test redesigned spacecraft systems after the failure of Korlab Sputnik 3 earlier that month. It carried a variety of biological specimens, as did the other Korlab missions, hence the need for urgent location of the craft in order that the effects of a launch abort on the test specimens could be studied.

The letter then speculates on the death of the cosmonaut, Illushin, after the mission. The origins of this rumour stem back to Dennis Ogden of the *Daily Worker's* article on 11 April 1961. This story has been shown to be based on speculation, and with greater openness on the former Soviet Space Programme no new evidence has emerged to support the story.

While I believe that full details of some aspects of the Soviet/Russian Manned Space Programme are still not fully available in the West, most pieces of the jigsaw are in place, and we can fairly accurately fill in the missing details, without recourse to old 'Missing Cosmonaut' stories.

J.G. PARRY
Gwynedd, UK

Sir, I write in response to A. Fellenberg's letter (**Spaceflight**, October 1993, p.349). On page 33 of Ref. 1 is a table listing all Soviet manned launches and related test flights. It states: "Although there have been a number of failures in the Soviet program, we have no evidence supporting the failure of any Soviet manned spacecraft". The report, originally classified Top Secret [Codeword], was dated March 2, 1967, nearly two months before the Soyuz 1 crash [1].

The Ilyushin story originated with a Moscow-based correspondent named Dennis Ogden. He picked up rumours of an impending Soviet manned space flight and knew that a test pilot named Vladimir Ilyushin (who lived in the same building as Ogden) had been injured. He developed the story based on this. Ironically, Ogden worked for the *Daily Worker* - the British Communist Party newspaper [2].

CURTIS PEEBLES
California, USA

References

1. National Intelligence Estimate # 11-1-67, The Soviet Space Program, March 2, 1967, LBJ Library.
2. James E. Oberg, Uncovering Soviet Disasters, (New York: Random House, 1988), Chapter 10.

First Manned Space Flight *(Continued)*

Sir, I thought the story about Ilyushin (***Spaceflight***, October 1993, p.349) had been knocked on the head years ago.

A whole load of Russians used to be listed in the *Guinness Book of Records* (11th edition, 1964, p.63), who tried and failed, allegedly, to return from space safely before Gagarin.

But, A. Fellenberg really should check his facts before writing about Project Mercury. Mercury Atlas 3 and 5, flew in 1961, not 1960. MA3 failed in April, when its Atlas booster was blown up, though the capsule was recovered intact. MA5 went in November and carried the chimpanzee Enos, who orbited the Earth twice before being brought back one orbit early.

Given that the US was trying to get the Redstone Mercury sub-orbital manned flights underway in 1961, the above is hardly an ideal preparation for US manned orbital flights before Gagarin in April 1961.

MIKE KITCHENER FBIS
Hertfordshire, UK

General Designer of KB "Salyut" Dies

Sir, Dmitri Alekseyevich Polukhin, general designer and director of the Russian Design bureau "Salyut", died September 7, 1993, according to an In Memoriam, published by the daily newspaper *Red Star* on September 10.

Polukhin started his career at KB "Salyut" as an engineer, after graduating from the Moscow Aviation Institute in 1950. He was involved in the development of the heavy launcher Proton (first launched in 1965), a series of military intercontinental rockets, and was responsible for the design of the space station Mir modules Kvant, Kvant-2, Kristall, Spektr and Priroda. The last two modules - now being tested at NPO Energiya in Kaliningrad - still await their launch to the Mir space station. Polukhin was a full member of the Academy of Sciences of Russia.

PETER SMOLDERS FBIS
The Netherlands

Cosmonaut's Tragic Death

Sir, On the report of the death of Sergei Vozovikov (not Vozovikanov, ***Spaceflight***, September 1993, p.305), I received another version while in Zvezdny Gorodok 6-15 August: first of all, Vozovikov drowned not on the 21st, but on 11th July. He was buried on the 15th.

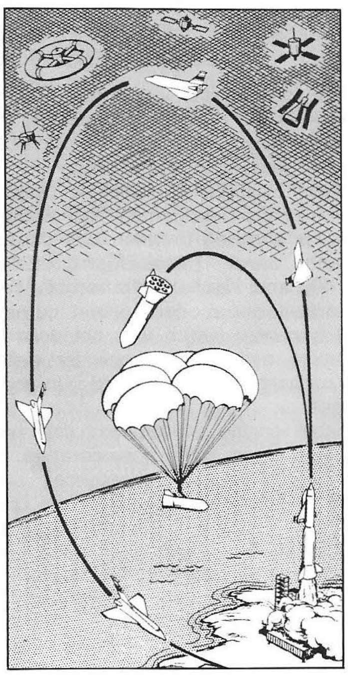
I was also told that the accident was not training related: he was said to have been snorkling and spearfishing for relaxation on a free Sunday between training sessions when he indeed got caught on a fishing net.

BERT VIS
The Hague, The Netherlands

Brian Harvey replies:
I welcome Bert Vis' comments. He may well be right in what he says. My report was based on the best information available at the time: these included official news sources. Like so many things in the Russian space programme, the full story does not always emerge at the very beginning.

'Space Launch' Competition

It is generally recognised that the cost of delivery of payloads to orbit needs to be greatly reduced if the enormous potential of space exploration and utilisation is to be fully realised. While engineers round the world grapple with this problem and assess the effectiveness of different launch systems, this month's competition provides an opportunity for *Spaceflight* readers to come up with the right answer and win a prize.



Prizes: The first five correct entries to be opened after the closing date of 2 December 1993 will receive a copy of the video:

Apollo Missions 4, 5 and 7

This video is a recent release which has now been added to the BIS video collection*. For further details see the announcement on the inside front cover of this issue.

Four types of propulsion device, denoted by the letters A,W,S,L, are available to the designer:

A	Aircraft	W	Winged rocket vehicle
S	Solid propellant rocket	L	Liquid propellant rocket

The flight path to orbit is divided into four sections in each of which one of the above types of propulsion operates, and the same type of propulsion may operate in more than one section of the flight path.

Technical constraints limit the designer's choice to eight possible launch systems, i.e. combinations of propulsion device, which are shown by reading the rows of the following table from left to right and the columns from top to bottom. The designer has calculated a 'cost index' for four of the eight launch systems as shown below.

To Enter: Find the values represented by the question marks and return the form giving the four letters of the launch system of minimum cost together with its 'cost index'.

					Cost Index
	A	A	W	L	?
	A	W	W	W	?
	A	S	L	L	26
	S	S	L	S	18
Cost Index	?	?	30	27	

ENTRY FORM

Title/Name ....

Address ....

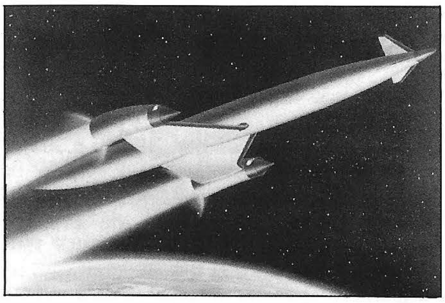
....

....

Launch System | Cost Index

Post to: The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, to arrive by first delivery on 2 December 1993.

* Tapes are VHS PAL format only and are not compatible with the US NTSC system.



SKYLON spaceplane. *Reaction Engines Ltd*

Space Launcher Design by Stages

Sir, Both Mr Todd and Mr Frata suggest in the July issue that Mr Bond's remarkable SKYLON concept should perhaps be preceded by a smaller air-launched test vehicle. Such a vehicle would be more closely related to the X-15 (single-stage, liquid fuel, runway landing, fully reusable) than the Pegasus (multistage, solid fuel, expendable). It is worth noting that the X-15, although suborbital, was the only fully reusable spacecraft built to date. With 199 flights in a programme costing about $6 million per year, it was also the least expensive.

Mr Bond and Mr Varvill reply correctly that the development cost of a subscale craft is only moderately less than that of a full-sized vehicle, and suggest it makes more sense to proceed directly to the operational design.

The space shuttle was developed in just this way, as a radical jump to a new full-scale design. Surprisingly, its development cost was predicted quite accurately. But the Shuttle's operating cost, originally predicted to be comparable to Mr Bond's SKYLON, was underestimated by a factor of at least ten; operating cost accounts for the vast majority of the total cost of the programme. Unfortunately predictions of operating cost (and reliability) are seldom accurate when a vehicle is radically different from its predecessors.

When design advances by stages, these costs can be better predicted. This is the approach being taken in the Delta Clipper programme. A subscale prototype reduces risk by filling in performance, reliability and cost uncertainties before the full scale vehicle is built. Design refinements suggested by a subscale prototype may be impractical once metal is cut on the full scale version.

A single programme combining subscale and full-scale vehicles will cost far less than the sum of the two programmes separately. How much less is difficult to say since the problems which will be avoided are precisely those which are currently unforeseen. But there is no more effective way to reduce technological risk.

Living a few miles from the free world's busiest launch site, I feel noise is not a major problem. Rockets are noisy close to the pad. However, since they depart almost vertically, the noise footprint is smaller than that of jets at a conventional airport. NASA gets more complaints about the shock wave of the returning shuttle than about launch noise.

On one point I am in complete agreement with Mr Bond. A manned prototype would be much more expensive than an automated one, both because of the requirement for life support and safety systems and because of interminable attempts, never fully successful, to eliminate every possible failure mode. This entails adding complex safety and monitoring systems which are sometimes less reliable than the systems they monitor.

Every radically new aerospace vehicle has had catastrophic failures during its development. For an unmanned vehicle, these failures can be accepted and costed out beforehand. For a manned vehicle, however, the inevitable and needless fatalities will bring years of recrimination and delay.

DANIEL WOODARD
Florida, USA

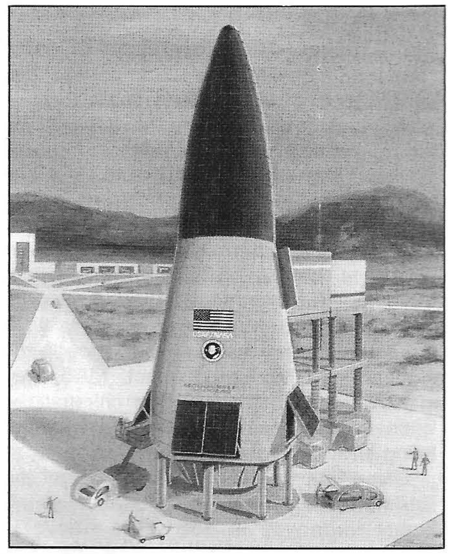
Delta Clipper, SKYLON Costs

Sir, I have recently seen some videotape footage of the successful first flight of the McDonnell Douglas Delta Clipper prototype DC-X and was very impressed not only by its flight but also by the fact that the one third scale suborbital vehicle has been built and is now flying for less than $60 million.

At a presentation given by Alan Bond and Richard Varvill at the College of Aeronautics, Cranfield, on 5 August 1993, they estimated that the SKYLON SSTO (Single-Stage-To-Orbit) spaceplane development and production would cost over $8 billion (in 1993 dollars).

SKYLON, in my view, is a technically better vehicle than Delta Clipper in that for a broadly equivalent launch costs (~$10 million per launch for both vehicles) the SKYLON launcher carries a significantly larger payload and is consequently more competitive on a per kilo basis. It seems however that on current estimated development costs, that when compared to Delta Clipper, it may be too expensive to build. SKYLON could be described as being the 'Rolls Royce' of SSTO launchers, whereas in the same way, Delta Clipper could be described as the 'Mini'.

Alan Bond has one ace left up his sleeve - his air breathing rocket engine designs, the RB545 and Sabre respectively. If in some way they could be used by Delta Clipper then its payload (and hence its economic efficiency) could be significantly increased. A large amount of LOX (liquid oxygen) required for the ascent and descent phases could then be saved and the engines' specific impulse would be significantly increased for the atmospheric phases of a flight., Of course the reduction in ascent LOX would be dependent on the .trajectory being optimised for air breathing, and this is in turn dependent on the lifting characteristics of the vehicle (e.g. the L/D(Lift/Drag) ratio). Delta Clipper is claimed as being able to achieve a cross-range capability of over 1,200 km which in turn implies a significant L/D. Even if a shallow ascent is not possible, some ascent LOX savings



Delta Clipper SSTO spacecraft. *McDonnell Douglas*

should still be possible. Of course the intake would have to be designed to avoid any ingestion of foreign objects during take off and landing (e.g. ground debris). This should not be a problem provided the inlets are high enough off the ground. I am sure that if this idea could be shown to be feasible then it would only be a matter of time before a true air breathing SSTO vehicle was built.

DAVID M. TODD
Middlesex, UK

Alan Bond and Richard Varvill reply:

We would like to offer some comments regarding the development cost of SKYLON following the letter from D.M. Todd.

Reactions Engines Ltd uses a project cost model for the development and production which is a hybrid between that due to Clegg and Janik (***Spaceflight***, 1967, pp.130-140) and Koelle's 'Transcost'. We have checked our model against current and past hardware (which was not used in its derivation) making allowance for deflators and exchange rates, and find it in good agreement.

The Sabre engine development cost has also been derived from consideration of programme activities and resources and this leads to similar conclusions to the cost model. Finally, Reaction Engines engaged the services of an aircraft sales consultant to perform a similar analysis. He returned a result 20% higher than our value, but this was explicable by the differences in assumptions.

This same model does not show Delta Clipper to be cheaper than SKYLON and if, as we believe, Delta Clipper will either have to increase in size or sacrifice cross range, it will be substantially more costly to develop and operate than SKYLON. SKYLON is *not* the 'Rolls Royce' of the spaceplanes, implying some unnecessary luxury. If space exploitation and exploration is to continue we must provide the most flexible and cost effective transport possible.

Our attention is continually focused on the operator and his economics with the intention of providing hardware which has minimal operational complexity and recurring costs. This in turn will offer the customer a large decrease in transport costs relative to any other system. There are no 'cheaper' intermediate solutions of which

we are aware and such compromise approaches only waste resources producing an unsatisfactory product (e.g. STS). We have, for example, recently begun the evaluation of SKYLON configuration C1 which employs a take off undercarriage on a conventional (though extended) runway with aircraft style cargo handling operations. We are examining spaceport layouts based around airport layouts and not launch pad layouts which are clearly not 'operator friendly'.

Finally, when comparing quoted costs one must question what is included and assumptions about reference dates. Reaction Engines quoted costs include vehicle development, finance interest and launch site operating costs together with operational activity, maintenance, insurance and range costs. Relative to January 1992 prices we expect an operator to be able to achieve $10.7 million per launch plus his profit. The payload to LEO would be 12 tonnes, and to a 460 km 28.5° space station 9.4 tonnes. These figures include the cargo container where applicable. The cost figures are subject to the traffic load of the operator. In the above scenario, for example, the vehicle would fly up to 200 missions and achieve obsolescence in 10 years. A world wide market of 30 vehicles is assumed with 100 missions per year. This model assumes that different operators have different traffic loads and that they use common international commercially owned spaceport facilities with price competition.

On the technical point in Mr Todd's letter, airbreathing engines are only useful on a vehicle having substantial lift, mainly for trajectory reasons, but also because of reliability, cost and operating noise levels. When these issues are taken into account, Delta Clipper with airbreathing engines transforms via HOTOL into SKYLON!

Lunar Space Shuttle

Sir, I was interested to read the hypothetical question on the recovery of Giotto and the answer given (***Spaceflight***, July 1993, p.283). These sorts of questions are currently in vogue in newspaper columns, and so I would like to pose one for your experts. Is there any way in its present format that the Space Shuttle could be made to achieve the necessary velocity to escape Earth orbit? For example, by using gravity assist or some other technique could it be placed on course for an orbit around the Moon and a subsequent return to Earth?

JOHN A. SILVESTER
Bedfordshire, UK

Roelof Schuiling replies:

The Space Shuttle main engines and solid booster rockets do not provide sufficient delta velocity to place the Shuttle on an Earth escape trajectory. Gravity assist would not be applicable in reaching a Shuttle escape trajectory, nor would the use of the manoeuvring engines provide enough additional thrust to reach escape velocity. It should be remembered that a shuttle orbiter, together with crew and payload, weighs about three times as much as the entire Apollo command, service and lunar modules combined.

Additionally, the orbiter was designed for an Earth orbital reentry and a translunar reentry would impart significantly higher aerodynamic and aerothermodynamic loads. Probably an orbiter would not survive such a reentry.

Olympus Mission Ends

During the night of 11/12 August, for reasons which are not yet understood, the Olympus satellite lost Earth pointing attitude and began spinning. This event, and the subsequent recovery attempts, used the last few kilogrammes of fuel remaining on the satellite. An assessment of the situation indicated that it would be impossible to re-establish service. It was therefore decided that the Olympus mission should be terminated and the satellite removed from the geostationary orbital ring.

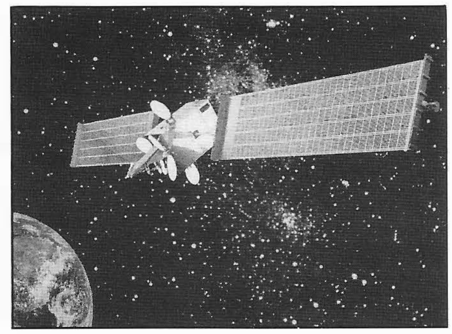
Olympus entered its fifth year of operations in July of this year. Throughout its mission, the satellite payloads were used by a wide range of European and Canadian Organisations to develop and test advanced satellite communications technologies and provide new services. It carried four separate payloads, a two channel high power direct broadcasting payload operating at 18/12 GHz, a four channel 12/14 GHz Specialised Services Payload, a 20/30 GHz payload for advanced communications experiments, and a 12/20/30 GHz beacon package for propagation experiments.

The Ka band 20/30 GHz payload was used to constitute the geostationary end of a data relay link between the Inter-Orbit Communications (IOC) terminal mounted on the ESA Eureca spacecraft and ground controllers and experimenters during that highly successful and recently completed mission.

Olympus has also been instrumental in the development of new applications, such as distance learning, data distribution and new commercial services. In the distance learning field alone, over 100 organisations in 12 countries have used Olympus to develop training courses which are now part of the established satellite-based educational infrastructure. Several of these operations have now been transferred to the Eutelsat space segment.

In the broadcast field, Olympus was the initial test bed for a number of satellite broadcast programmes, which are now running on a commercial basis, including RAISAT and the BBC World Service. It was also used for experimental high definition TV broadcasts, to assist in the development of that new technology.

It will be remembered that control of Olympus was accidentally lost in the summer of 1991 [1] and, following an uncontrolled orbital drift around the world in a frozen state at temperatures of some minus 60 degree Celsius, the satellite was the subject of a spectacular recovery action which allowed it to be put back into service again. The recovery at that time, however, used a large amount of fuel, and little was left on-board to complete the intended five-year mission. By instituting new procedures to conserve fuel, it was never the less hoped that Olympus could complete its nominal five year mission in early 1994 and then still have a reserve amount of fuel that could be used to re-orbit the satellite, i.e. remove it several hundred kilometres from the geostationary orbital ring. This re-orbiting at the end of a geostationary satellite mission is ESA policy in order to eliminate the probability that a satellite left to drift in that orbit could later strike or interfere with another satellite.



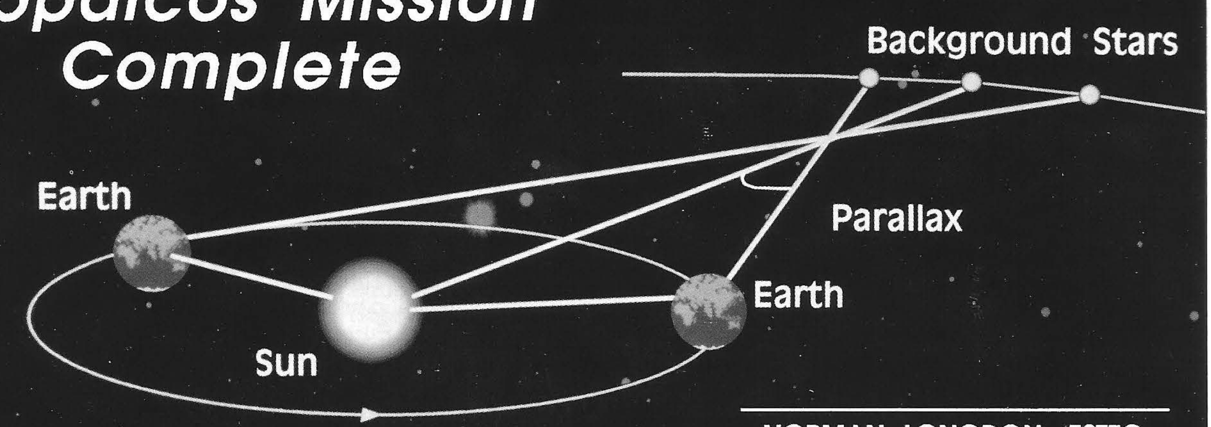
An illustration of the Olympus satellite in orbit. Olympus was constructed for the European Space Agency by an international team under the leadership of British Aerospace. *ESA*

When on the night of August 11 the satellite lost Earth-pointing, an automatic mode change was initiated, but the on-board control loops were not immediately successful in despinning and reorienting the satellite. The firing of thrusters caused an orbital drift and used much of the remaining fuel. Actions then had to be taken by the spacecraft controllers on the ground to over-ride the automatic functions and manually control the satellite. These actions were successful, but the amount of fuel still available would not have been sufficient to re-establish the three-axis controlled attitude of the satellite, stop its orbital drift, return it to its proper position in the geostationary ring and still retain a margin for eventual withdrawal from the geostationary orbit. It was therefore decided to initiate re-orbiting at once. It was also decided to re-orbit to a lower rather than higher altitude due to the fact that the thrusters had already caused an orbital perturbation in this direction, and, consequently, there would not have been sufficient fuel to retransfer the spacecraft to a higher orbit.

Reference

1. Dave Wilkins, 'The Olympus Recovery: "Mission Impossible?"', ***Spaceflight***, November 1991, p.384.

Hipparcos Mission Complete



NORMAN LONGDON, ESTEC
Interviews
Dr Michael Perryman
ESA Hipparcos Project Scientist

The position of a particular star relative to the general star background is displaced as the Earth revolves around the Sun (taking the observer or observing instrument with it). The 'parallax' of a star is the angle that it subtends at the Earth's orbital radius.

Astrometry Reaps a Rich Harvest of Data

Hipparcos (High Precision PARallax COllecting Satellite) is reminiscent in pronunciation of Hipparchus, the Greek who by 120 BC had calculated the distance of the Moon from the Earth. During its four years of operation, this satellite has given astrometry a great boost, and astronomy generally a whole new range of data to sift through.

But who better to tell the story than Dr Michael Perryman, the ESA Hipparcos project scientist, who has been at the centre of events for more than a decade. Norman Longdon was fortunate to meet this enthusiastic and dedicated scientist, and to put a few questions to him.

* * *

Did Hipparcos Fulfil the Scientific Purpose for Which it was Built?

We can say that it did, without any reservation!

Hipparcos, which is the first satellite devoted to astrometry, was accepted by ESA in 1981 with certain very specific objectives. Such a mission would provide a fundamental advance if it could measure the positions, parallaxes, and annual space motions of about one hundred thousand stars, with a mean accuracy of about 2 milli-arcseconds for each parameter.

The accumulated observations over the satellite's time of operation from August 1989 to August 1993 will ultimately deliver considerably more than these original goals: nearly 120,000 stars have been measured, and final accuracies will be in the range 1-2 milli-arcseconds. A further million stars have been measured as part of the Tycho experiment, which was added to the satellite during the development period. For all these stars, Hipparcos will provide good estimates of their positions, with unprecedented accuracy, estimates of their distances, and their velocities through space, indications of whether they are binary systems or not, and an enormous collection of information about their photometric properties - for example, their colour, and whether they are variable or not.

The measurements made by Hipparcos therefore meet, and in many cases significantly surpass, the original goals.

120,000 stars measured with accuracies of 1-2 milli-arcseconds. Another one million stars measured to a lesser degree.

Their eventual scientific impact must wait until the astrometric catalogue is finalised and published. We anticipate that some very interesting astrophysical problems will be addressed using the data, furthering our knowledge of our Galaxy, its dynamical structure and evolution, its stellar content, and properties (such as the distribution, luminosities and masses) of the stars, especially in our region of our Galaxy.

A Mission of this Nature Must Seem to Many Non-Scientists to Have No Great Relevance to today's World. Why was it so Important to be Funded and Realised?

Astronomical observations have long played a central role in man's understanding of the natural world. Indeed, from about the year 1500 until the middle of the last century, the astronomer's foremost task was the measurement of celestial positions. In an excellent study of the development of critical angular measurement in astronomy (Dividing the Circle, by Allan Chapman, Ellis Horwood, 1990), the author notes that:

"To the early Astronomers Royal, the heart of astronomical investigation lay in the stellar parallax, the longitude, and the explanation of Newton's laws".

Essentially, without accurate data it was impossible to settle many and varied theoretical issues. Without improved angular measurement techniques,

"Celestial mechanics would have been devoid of that foundation of observable data necessary for its growth as an inductive science, while cosmology could never have risen above the level of speculation".

Over the last century, many advances in astrometric techniques and measurements have been made, usually requiring sophisticated instrumentation or reduction techniques to minimise the effects of the Earth's atmosphere, and related problems, on the determination of stellar positions. Typically, these measurements have not been able to reach the theoretically achievable instrumental limits, and the accurate measurement of stellar distances has remained a very challenging, if not an all but elusive task, for a variety of reasons.

With a satellite capable of making highly accurate positional measurements from space, the problems of the Earth's atmosphere, the limited sky coverage of any individual Earth-based telescope, and problems such as gravitational and thermal instrument flexure, can all be overcome. The accuracies achievable become essentially limited by the optical system flown. As a result,

Hipparcos has achieved a massive advance in both the quality and quantity of these difficult angular measurements so critical to an understanding of stellar properties. When the Hipparcos and Tycho Catalogues are finally available for scientific exploitation, we may expect corresponding resurgence in interest in this ancient and fundamental science, and a sudden advance in many astronomical areas that have laid relatively dormant over the past few decades.

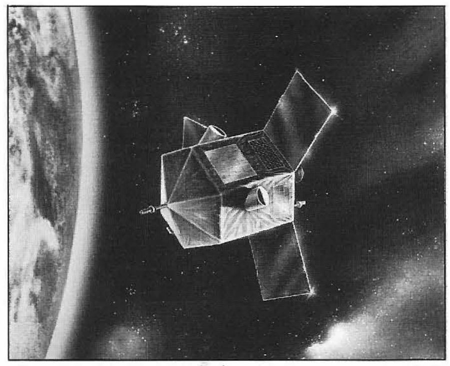
Perhaps I should give an illustration of the task that we faced. A milli-arcsecond (or one thousandth of an arcsecond - an arcsecond being one sixtieth of one sixtieth of one degree) is the angle subtended by a golf ball in America as viewed from Europe, or by a person on the Moon as viewed from the Earth. These distances are so large, and the corresponding angles so small, that they are still not easy to comprehend. To give another example, human hair grows by about that angle, viewed from 10 metres away, in about ten seconds! To make these angular measurements, we employed a telescope in the satellite that is so accurate, that if the mirror was scaled up to the size of the Atlantic Ocean, the peaks and valleys resulting from the mirror's imperfections would nowhere exceed 10 cm in height!

Such excessively high angular precision is absolutely necessary to understand more about the Universe in which we live. To take a specific example there are about 3000 stars known within a distance of about 25 parsecs, or 80 light-years, from the Sun. To measure the luminosity, or mass, or radius, of such a star, we need to be able to measure its distance accurately; despite the fact that a star at 25 parsecs is still relatively nearby in astronomical terms, it is actually some one thousand million million kilometres distant, or some five million times further away than the Sun; and at this distance, a star moving at a typical speed of say 10 kilometres a second, despite moving more than 300 million kilometres in a year, will still take more than 20,000 years to move by an angle equal to the diameter of the full moon!

Hipparcos will therefore provide us with a very detailed three-dimensional picture of our region of the Galaxy - a sort of stellar census, which has never been carried out with such care and precision before.

What In General Terms are the Most Significant Results, at Least as They are Known at Present?

We are in the middle of probably the largest single data analysis problem ever undertaken in astronomy: about 1 Gbit (one thousand million bits - in terms of information, something like 50 times the complete works of Shakespeare!) of satellite data were acquired each day for more than three years, and all of these data have to be processed together in the creation of the final catalogue. The global nature of the analysis, like a giant scientific jigsaw, means that we cannot really examine the astronomical results, in any serious way, until the catalogue is available, and the astrophysical interpretation begins.



Hipparcos. *ESA*

However, even now, we can see convincing evidence for systematic, zonal, positional errors that exist in ground-based catalogues, as well as general and very significant improvement in the individual star positions. Future observers will be able to capitalise on these improved positions as reference stars for photographic plate or meridian circle reductions, and our first tests here have demonstrated just how good these future reductions are likely to be. Good optical stellar positions are important for numerous reasons: as a reference system (for example, for interplanetary navigation: the early Hipparcos positions have already been used by the Galileo programme in their recent flyby of asteroid Ida), and for the registration of celestial maps in other spectral regions, especially in the radio region where an excellent reference frame exists already.

The parallaxes, or distance estimates, that we are getting from the global solution look highly encouraging, and the thousands of accurate stellar distances that we have so far obtained form a very tight correlation between star colour (or temperature) and absolute magnitude, constituting the famous Hertzsprung-Russell diagram. This is the most fundamental correlation amongst stellar properties known: its detailed features will provide stringent constraints on stellar evolutionary theories, and a rigorous framework for exploring the evolutionary history of our Galaxy as a whole.

Several thousand double star systems have been discovered by the satellite, and we are in the process of determining their separations and other geometrical properties. Many new variable stars, including periodic variables and eclipsing binaries, have been discovered; and the data analysis already provides a rather convincing confirmation of the gravitational light bending predictions of General Relativity, at an improved level with respect to previous measurements based on radio VLBI.

How Is the Scientific Community Organised to Analyse the Results?

The Hipparcos programme has been a huge collaborative venture between ESA (which funded and managed the satellite development and manufacture and carried out the satellite operations) and four European scientific teams, comprising more than two hundred individuals from

What is Astrometry?

Astrometry is perhaps the least well known of the space research disciplines, yet it is a fundamental science upon which many other disciplines associated with astronomical studies depend for basic information.

The dictionary defines astrometry as *the branch of astronomy dealing with the geometrical relations of the celestial bodies and their real and apparent motions.* Astrometric measurements of stars, and bodies within the Solar System, seek to determine the positions of these objects within a consistent reference system at a given time, and to study how these positions change with time.

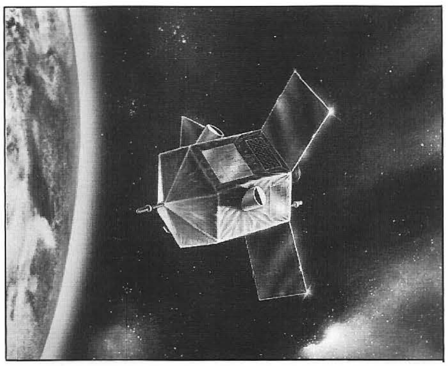
Astrometry has a long history, going back to 240 BC, at which times the Greeks had determined that the Earth was a sphere, and Hipparchus had by 120 BC calculated the distance of the Moon from the Earth by measuring the Moon's parallax. A comparison of his star map with the work of his predecessors led to the discovery that the Earth's rotational axis slowly changes its direction.

Nothing really happened during the 'dark ages' (the same being true of other branches of science) until Tycho Brahe, following Copernicus' rediscovery of the heliocentric concept, carried out a long series of observations during the second half of the sixteenth century, using his brass azimuth quadrant. Kepler used these observations when formulating his laws of planetary motion.

Sixteen hundred and nine is a most significant date in astrometry. The invention of the optical telescope opened up great possibilities. The angular error in astrometric measurements fell to 15 seconds of arc by 1700, and to about eight seconds of arc by 1725. This made it possible to detect stellar aberration (small positional displacements due to the vectorial addition of the velocity of light to the Earth's orbital velocity, and nutation (an 18.6 year wobble in the Earth's spin axis produced by the gravitational influence of the Sun and Moon).

Edmund Halley calculated the rate of precession by comparison of contemporary observations with those of Hipparchus. He correctly concluded that the measurements showed that several stars had a proper motion of their own. During the eighteenth century this work was intensified.

Astrometry welcomed the invention of the photographic camera as it extended still further ground-based observations, but the improvement of accuracy was never better than about 20%.



Hipparcos. ESA

universities and scientific institutes. One of these teams was responsible for compiling the list of stars to be observed by the satellite and the publication of the 7-volume Hipparcos Input Catalogue in 1992. One scientific consortium is responsible for the analysis of data constituting the Tycho experiment, while two teams are responsible for the independent analysis of the main mission data. Analysis of the data from the main experiment is such an enormous and complex task, that it was decided that this would be best carried out by two separate teams, who essentially provide an unprecedented degree of cross-checking and verification of each other's analysis: these analyses (which run to hundreds of thousands of lines of executable software) differ in countless details, and the eventual creation of a catalogue which agrees very well between the two groups will ensure the quality of the final results.

After launch, in August 1989, data were sent to the three analysis teams concerned. Logistical and administrative details differ within the various scientific teams but typically data were sent from ESOC, near Darmstadt (Germany) on magnetic tape to one institute in each of these teams. The first stages of the data treatment are then carried out, resulting in intermediate quantities, and generally a reduction in the quantity of the data. These results are then passed to other institutes, which carry out the next stage of the processing, and so on. As a result of the ongoing analysis within these teams, and the verifications within the various interconsortia, a very large amount of Hipparcos data is actually flying backwards and forwards across Europe, between institutes and individuals, on magnetic tapes or via electronic mail networks. A cross-consortium group, the Hipparcos Science Team monitors the progress of the groups.

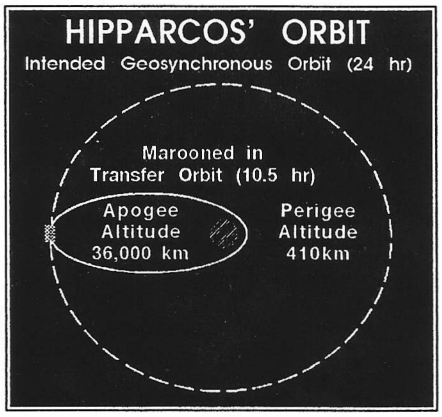
Most of the ESA member state countries are playing a significant role in these scientific tasks, with all of the major astrometric institutes in Europe (as well as many others) involved. The UK plays a major role in one of the data analysis teams, with a small and highly efficient group at the Royal Greenwich Observatory in Cambridge involved in various stages of the data treatment.

This organisation has worked extremely well. It helps that we have very clearly defined experimental objectives, but the analyses are lengthy, complex, and the administration of such massive amounts of data is a monumental task in its own right. The collaborations have functioned really very well indeed.

Would you take us through some of the Memorable Moments (both Good and Bad) in the Lifetime of the Hipparcos Mission?

The ESA project team, and the industrial project team (35 European firms), worked for about eight years on the satellite design and construction. A general highpoint was simply working with these teams over the years, and seeing how problem after problem was solved through a combination of determination and skill on the parts of hundreds of people. We had many setbacks, but a common desire to achieve a particularly ambitious objective kept motivation levels very high for a very long time.

The launch was a remarkable moment. It was a night launch, and all the more dramatic for that, but to watch the fruits of so many years of delicate effort, perched on top of the huge Ariane rocket, and then thunder away into the sky, shaking the ground all around, was a remarkable experience. It seemed unimaginable that such a delicate piece of engineering could possibly withstand such a journey, and it was strange to think that something that we had worked so closely with for so long was now beyond reach, and would remain that way forever.



Two days after the launch, ESOC uplinked the telecommand to initiate the firing of the satellite's apogee boost motor, the motor which would circularise the orbit into its geostationary position. We heard that the command had been unsuccessful as we were boarding the flight returning from the launch site in French Guyana, and our return to Europe, was in consequence, not at all the pleasant journey that we had been looking forward to. We made our way straight to ESOC, arriving after midnight, and learned of the motor firing attempts that had been made subsequently. Other efforts were made over the next few days, without success. The experiment was consigned to an orbit for which it was not designed, and there was general pessimism about the mission's long-term prospects. After so many years of continuous effort, by so many people, we felt that success had been snatched away from us at the last moment. Not only did we think that the experiment would not succeed, but we felt that we would not - and perhaps would never - be given the opportunity to prove that the mission concept was valid. This was a difficult period, complicated by the enormous efforts that were then necessary to try to get the most out of the satellite in this orbit. Fortunately, all groups involved, including the ESA scientific advisory committees, rose to the challenges demanded of them.

Over the subsequent months and years, many people, especially those members of the mission operations team at ESOC, responded brilliantly to the very difficult operational tasks that they had been presented in the unplanned orbit. During this period there were again several setbacks and difficulties, several of which seemed insurmountable at the time, but which again eventually proved soluble by inventiveness, commitment, and not a little good luck.

Lastly I would mention the permanently spirited involvement of the scientific teams that are working with ESA in the project, people whose scientific vision nurtured and created this ambitious programme, and whose dedication, in some cases over a period of nearly twenty years, had taken it from its first hazy concept into something that will provide a valuable scientific legacy for future generations of astronomers.

What is the Future for Astrometry and are More Space Missions Likely?

The Hipparcos results will only gain a complete and broader understanding within the astronomical community once the final catalogues are published in about three years from now.

Many scientists are going to be thoroughly surprised at the breadth of astrophysical issues that will be addressable with the Hipparcos data. Then, following on from a resurgence of interest in stellar and galactic problems inspired by the quality of the Hipparcos data, more questions will be asked, and more weight will be thrown behind new proposals to achieve yet better astrometric measurements.

Achieving sub milli-arcsecond accuracies will probably only be possible from space, and it would be good to think that Europe's pioneering work in this field will find sufficient support to embark on a follow-up mission. It would be nice to think that I might still see a yet more ambitious astrometric programme, probing deeper our understanding of the Universe and operating in my lifetime.

Mission Fulfilled

Hipparcos has now been honourably retired, its mission fulfilled. For the scientists, 'phase three' is now well under way, as the data are sifted and analysed. All the indications are that there will be many more exciting discoveries, puzzles to be solved, perhaps unforeseen questions to be asked. Astrometry has its central role back; the spirit of both Hipparchus and Hipparcos is very much alive.

Astronomical Notebook

Double Quasar Found

The recent discovery of the brightest known double quasar would not have been possible without some luck. Double image may be due to gravitational lensing.

What began as a normal inspection of a photographic plate obtained with one of the ESO telescopes has now resulted in the identification of a unique celestial object.

Besides being of great interest in itself, the new quasar (designated HE 1104-1805 AB) may provide an independent estimate of the distance scale of the universe. It is also eminently suited for study of the structure and composition of the mysterious absorbing gas clouds in the early universe.

More than 5000 quasars are now known but most are faint points of light which can only be studied with large telescopes. Quasars bright enough to be seen in detail with different techniques at all wavelengths are quite rare.

The two objects of HE 1104-1805 AB form a quasar pair with a separation of 3.0 arcseconds and have very nearly identical spectra. The measured redshifts, $z = 2.303$, are also virtually equal, which indicate that the pair is moving away from us at a speed of ~250,000 km/sec. This corresponds to a look-back time of 83% of the age of the Universe, i.e. we see them as they were when the Universe was less than one-fifth as old as it is now. Assuming the age of the Universe to be 20,000 million years, the distance to this quasar would be about 16,000 million light-years. The brighter component A has a visual magnitude 16.2, while that of B is 18.0, so A is more than 5 times brighter than B and the brightest known object of its kind in the sky.

The similarity of the spectra indicated at first that A and B may, in reality, be two images of the same distant quasar, whose light has been bent by an object situated between the quasar and us. If so, the quasar light would reach us via two slightly different paths, with two images of differing brightness seen of the same object. This strange phenomenon is called gravitational lensing.

On closer inspection, however, there were small but distinct differences between the spectra of the two components. These are exactly what would be expected if component A is amplified by the effect of microlensing due to one or more stars in a distant galaxy being near the line-of-sight to the quasar. It will be easy to test this hypothesis since the differences between the spectra of A and B, as observed in May 1993, would then disappear after a few years. If it does not, then HE 1104-1805 AB must be a genuine pair of quasars and the two images seen are of two different quasars situated near each other in space. They may even orbit each other in a binary quasar system.

Should it turn out to be a gravitational lens object, HE 1104-1805 AB may be used to monitor the time delay of the future brightness changes of the two images, i.e. how much later one component will mimic the changes of the other. This measurement, which is quite easy for an object as bright as this, will provide a completely independent way of determining the distance scale of the universe.

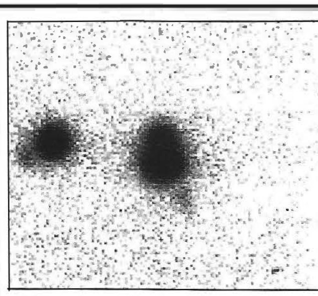
Observations with the IUE (International Ultraviolet Explorer) satellite, performed on April 29, after discovery of the new object, confirm that HE 1104-1805 AB is also very bright in the ultraviolet spectral region and will therefore be a relatively easy target for the HST.

The ROSAT All Sky Survey shows that the new double quasar is a strong X-ray emitter so it will be important to find out whether these X-rays are from the quasar itself or are due to an intervening cluster of galaxies. Further observing time with the ROSAT satellite observatory has already been granted to allow further study this interesting object.

Brightest Known Double Quasar

The newly discovered 16-magnitude double quasar HE 1104-1805 AB is the object at the centre of this CCD image, obtained on May 11, 1993. Component A is the brighter of the two (lower) and B is the fainter (upper). The distance between the two objects is 3.0 arcseconds. This image is a composite of three 200-second exposures through a red filter.

The bright object to the left is probably a galactic star. The diffuse, faint object South-West (below and right) of the quasar is a 21-magnitude galaxy. It is too far away to be the "lensing" galaxy which may have caused the splitting of the quasar image.



European Southern Observatory

Nova Cygni 1992: Gas Shell Emerges

NASA's Hubble Space Telescope (HST) has given astronomers their earliest look at a rapidly ballooning bubble of gas which blasted off Nova Cygni 1992, one of the brightest novae in 20 years, which erupted on February 19, 1992.

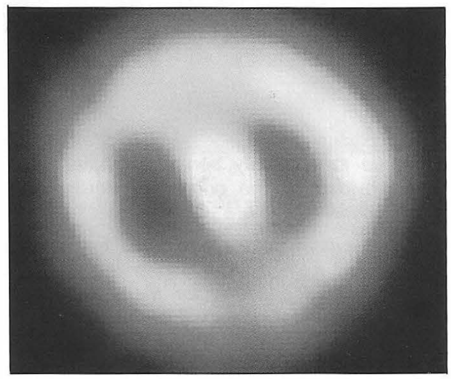
The HST image reveals a remarkably circular yet slightly lumpy ring-like structure. The ring is the edge of the bubble's shell of hot gas. The shell's diameter is calculated from its expansion velocity (as measured from ground-based observations) and found to be 37 billion miles, or 400 times the diameter of the Solar System. The distance to Nova Cygni then follows from the ring's angular size and turns out to be 10,430 light-years.

A striking relic of the explosion is an unusual bar-like structure across the middle of the ring, which might mark the edge-on plane of the orbits of the two members of the binary system.

A large amount of gas stirred up along the plane would make the shell denser in the plane of the orbit of the double star though an alternative possibility is that the bar is produced by twin jets of gas ejected for the star and spanning the distance between the shell and the star.

A nova occurs in a double star system where one member is a normal star and the other is a white dwarf which pulls material from its stellar companion. This material accumulates on the white dwarf's surface until pressure and temperature increase to the stage where thermonuclear reactions take place.

A nova is a thermonuclear explosion that occurs on the surface of a white dwarf star in a double star system. The entire white dwarf's surface explodes as a gigantic hydrogen bomb releasing as much energy as our Sun produces in 1,000 years. As the expanding shell of hot gas envelopes both stars, they continue to orbit inside it. This should produce a thick disk of gas created through the "eggbeater" motion of the two stars. The bar in the Nova Cygni 1992 image might be the relic of this event.



An HST image of Nova Cygni 1992 taken in ultraviolet light with the ESA Faint Object Camera on 31 May 1993, 467 days after the explosion.
Francesco Paresce, ESA/STScI and NASA

"This is the first time we've been able to separate a white dwarf star from the ejecta so early in the nova event", said Dr Francesco Paresce of the European Space Agency and the Space Telescope Science Institute, Baltimore. This shell will not be resolved from the ground for at least another 5 years and by then it will have been deformed and been chemically contaminated by passing through other material around the star. Being so young it still contains a record of the initial conditions of the explosion and this will allow astronomers to construct the early history of a nova explosion.

Watching the evolution of the shell will also reveal how heavy elements, processed in the star's envelope, are ejected back into space. Such explosions enrich space with elements such as oxygen, carbon and silicon that are the fundamental building blocks for new generations of planets, and presumably of life.

BOOK NOTICES

These notices, compiled by L.J. Carter, are not intended to be reviews in the ordinary sense but have been extracted from information provided by the publishers and/or authors, amplified by further brief comment where appropriate.

Full publication details are given for each book to enable copies to be ordered from a local bookseller, if desired. The address of each publisher also appears, for many items can now be ordered direct from them. If not, they will supply the address of a local agent who can handle matters.

Star Formation, Galaxies and the Interstellar Medium

Eds., J. Franco, et al., Cambridge University Press, The Edinburgh Building, Cambridge, CB2 2RU, 393pp, 1993, £40.

The spectacular and enormously powerful star-formation events seen in some galaxies often come about as a result of interactions between galaxies. Interest in this subject has greatly expanded since the discovery by IRAS of infra-red bright galaxies in 1986 and an intriguing implication of this work on starbursts is that active galactic nuclei may not be powered by accreting black holes after all. Compact regions of dust-enshrouded star formation may, instead, be the driving activity, with supernova exploding roughly once a year in massive nuclear concentrations of gas.

This book is a collection of both review articles and those describing recent advances. It relates observations of gas and star formation in normal galaxies, starbursts in galaxies and active galactic nuclei and discusses new models to explain all these phenomena. Additionally, it details the interaction between massive stars and their environments, describes observations of star complexes and specifies models for large-scale formation.

These are the truly gigantic systems of interacting galaxies, found through their ultra high infra-red luminosity. They are fascinating not only because of their incredible scale but because they appear, in some cases, to be spawning gas and stellar entities which become small galaxies.

The book is divided into four main sections i.e. gas and stars in normal galaxies, active galactic nuclei and starbursts, stellar energy input and scenarios from large-scale star formation. Together, the articles comprise a thorough review of the most important developments in galactic-scale star formation since the starburst revolution began.

A Journal for Christa: Christa McAuliffe, Teacher in Space

G.G. Corrigan, University of Nebraska Press, Academic & University Publishers Group, 1 Gower Street, London, WC1E 6HA, 1993, 191pp, £21.

Christa McAuliffe died with her astronaut companions in the Challenger explosion on 28th January 1986. She was a young school teacher chosen to be the first civilian to go into space.

In this Memoir, her Mother, invokes family history, notes and letters and other commemorative data to honour her daughter and to provide a very personal biography of a remarkable young woman, little known beyond her immediate circle until she was selected by NASA to fly on the Shuttle as the first Teacher in Space.

Whether the initial selection was a publicity stunt or not, it may have proved more than NASA had bargained for Christa McAuliffe was direct, outspoken and impatient with Government bureaucracy. She did not hesitate to speak out on behalf of those she thought herself selected to represent. She regarded this as a tremendous responsibility but one which she accepted because she felt her experience would enhance the role of teachers, inspire students and thereby improve education.

The account not only embraces Christa's early years but covers her selection and preparation for the Shuttle flight. It concludes by relating some of the events which took place after the launch and thereby brings the story up to more recent times.

Protostars and Planets III

E.H. Levy and J.I. Lunine, The University of Arizona Press, 1230 N Park Avenue, Suite 102, Tucson, Arizona 85719-4140, USA, 1596pp, $90.

The frontiers of astrophysics are being pushed back, simultaneously, in two opposite directions. The first is towards larger and grander scales, in an effort to understand what we know as our Universe. The second is towards smaller and smaller scales, to help understand the formation of stars and planets, with man regarded as a phenomenon, possessing a deep-seated motivation to understand himself in relation to the universe, of which he forms part, and to grasp the possibilities that the universe offers in terms of planets and life elsewhere.

This new book continues two earlier volumes in the series which address fundamental questions concerning the formation of stars and planetary systems in general and of our own solar system, in particular. It summarises our current understanding of these processes, drawing on recent advances in observational, experimental and theoretical research.

Among the subjects covered in more than three dozen chapters are the collapse of interstellar clouds and the formation and evolution of stars and disks, nucleosynthesis and star formation, the occurrence and properties of disks around young stars, T Tauri stars and their accretion disks, gaseous accretion and the formation of the giant planets, comets and the origin and long-term dynamical evolution and stability of the solar system. It reflects the impressive advances which have taken place over the last two decades, e.g. observations have now made the very cores of star-forming complexes open to scrutiny, revealing their disk-shaped assemblies of dust and gas which look, for all the world, as precursors of planetary systems. Another item of particular interest is how protoplanetary disks transport mass and angular momentum. Only recently have theorists tried to face this issue.

The volume summarises a field in which progress is advancing rapidly and gives a good indication of the variety and intricacy of processes which, in creating stars and planets, drive much of the physical and chemical evolution of galaxies.

Man in Space: An Illustrated History of Spaceflight

Ed. H.J.P. Arnold, Smithmark Publishers Inc., 16 East 32nd Street, New York, NY 10016, USA, 1993, $29.95.

When the first tiny satellite, Sputnik 1, was launched in 1957 by the former Soviet Union few people recognised that it was to be the beginning of an extraordinary new chapter in man's history.

Major American and Soviet Space Programmes grew from this small beginning, inspired by the vision of scientists and engineers and the courage of the first astronauts and cosmonauts.

Many significant milestones have already been passed. Twelve Apollo astronauts have walked on the Moon's surface, probe craft have explored our planetary neighbours and Soviet cosmonauts have lived and worked in space for periods of up to a year at a time.

Space exploration also touches our lives in less spectacular but no less important ways. Communications satellites give us access to our neighbours, Navsats act like small radio beacons to assist aircraft and ships to navigate accurately while environmental satellites have already revolutionised meteorology and are destined to play an ever greater role in monitoring the environment of our world.

This is an absorbing story, ably presented in this compendium with the aid of lucid text and well over 600 pictures, many in colour. It highlights all the major space events which have taken place so far and interweaves their important background themes e.g. the rivalry between the super powers in the 60s and 70s, the rise of space interest in China, Europe and Japan and the increasing commercialisation of space.

Pauper and Prince: Ritchey, Hale and Big American Telescopes

D.E. Osterbrock, The University of Arizona Press, 1230 N Park Avenue, Suite 102, Tucson, Arizona 85719-4140, USA, 359pp, $45.

Ritchey was a telescope designer interested in new methods of making large astronomical mirrors. He worked so closely with Hale, a successful fund-raiser, that Mount Wilson Observatory today stands a monument to their collaboration. Yet their very success led to tension, estrangement, and finally to Ritchey's dismissal and banishment by Hale.

Nowadays, Ritchey is associated with the Ritchey-Chretien system used in large telescopes, the 60 inch Mount Wilson Telescope and the 100 inch Mount Wilson Mirror, so today's large instruments have demonstrated the validity of his predictions which must have seemed fantastic to the astronomers of his day.

Ritchey is relatively little-known so this book fills the gap by describing his life and career, drawing on letters preserved in astronomical archives and on interviews with those who knew him personally. It focuses on his work in perfecting the methods of making large parabolic mirrors for reflecting telescopes and pioneering their use in astronomical photography. It also reveals how pride, ambition and individual personalities combined to affect the development of scientific knowledge and technology which led to the development of major American astronomical facilities and then to Ritchey's subsequent dismissal and banishment from the astronomical scene.

The Sky: A User's Guide

D.H. Levy, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1993, 295pp, £9.95 (Paperback).

Anyone wishing to make a start in astronomy could do well to begin with this handy volume. It caters for all ranks, from the observer using only his naked eyes to those able to make quite sophisticated observations. The style is non-technical but lively and interesting and full of practical hints. It puts amateur observation within the framework of a leisure activity which is bound to provide much personal satisfaction. Basically, it is divided into three sections. The first is all about getting started, though references to selecting and choosing a telescope while useful, are somewhat brief for the emphasis is largely on conducting practical observations. This is the approach continued throughout the book in the two following sections, one on observing the bodies that comprise our Solar System and the other on deep sky studies.

The author is well-versed to write such a book. He has had considerable success in observational astronomy, himself, with the discovery of 17 comets to his credit and minor planet 3673 named in his honour.

An Introduction to Astronomical Photometry

E. Budding, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1993, 272pp, £30.

Astronomical photometry is about the measurement of the brightness of radiating objects in the sky. This book deals mainly with optical photometry which centres on that region of the electromagnetic spectrum to which the human eye is sensitive. This denotes the relevant spectral range, which coincides with the important "window" through which external radiation can easily pass.

It is designed to encourage interest in the practical aspects of observational astronomy, geared to the needs of the University and other Research Students, as well as advanced amateur astronomers.

The aim is to provide an understanding of physics from a database perspective. So, starting from an overview, an historical background and a glossary of terms, the underlying physical principles are examined along with more wide-ranging questions on current astronomical photometry. Photometer design and applications of photometry to astrophysical topics are also included.

The central two chapters deal with principles of photometer design, including recent advances and some common data handling techniques, while the remainder of the book presents applications of photometry to selected topics in stellar astrophysics.

Each chapter begins with preparation material before moving on to technical and formally presented text.

Basics of Space Flight

L.M. Celnikier, Editions Frontiers, BP 33, 91 192 Gif sur Yvette, Cedex, France, 1993, 356pp, Hardback $51, Softback $36.

In this volume the author shows how well-known and relatively elemental laws underline all practical developments in space flight and thus indicate what is possible and what not.

Wide-ranging chapters collect together a wealth of information on all the significant matters involved, though some knowledge of mathematics is required if the reader is to evaluate them to the full.

The author begins by dealing with the mathematics of space flight. Here he points out that the Universe can be regarded as a collection of, more or less, deep gravitational wells, in which are embedded the planets, satellites, stars etc., thus leading to the concept that a rocket designer needs to secure the energy needed to move up these "walls", if his craft is to venture into space. This, in turn, embraces not only trajectories and orbits but also the means of propulsion. The requirements of nuclear propulsion, including development of the fusion rocket, receives a chapter all to itself in contemplating alternative methods of deep space travel.

Other matters considered are the questions of rocket staging, to optimise performance and problems of re-entry. Additional aspects discussed are the problems of space communication, spacecraft stabilisation and navigation and those which relate, particularly, to the Earth's ionosphere.

A final chapter is devoted to relativistic flight and a number of useful Appendices conclude the volume.

Valentina - First Woman in Space - Conversations with A. Lothian

The Pentland Press Ltd., Hutton Close, South Church, Bishop Auckland, Durham, DL14 6XB, 1993, 410pp, £17.50.

This book has been published to commemorate the 30th Anniversary of the flight of Valentina Tereschkova in Vostok 6 (16th-19th June 1963), the first woman to venture into space as well as the first to pilot a spacecraft.

It is actually about two people. The first is the authoress, herself, who uses the first half of the book to describe meeting Valentina at various Congresses, Celebrations and Ceremonies. The second is a series of interviews conducted by the authoress in which Valentina is invited not only to reply to questions on her training and actual space flight, a section which occupies only 24pp, but to respond with comments and opinions on wide-ranging subjects such as the modern family, the ecological harmony needed to protect our planet, global morality etc.

Also included in this second half, however, are accounts of her childhood in Stalin's Russia, her factory work, parachute training and how she secretly joined the Soviet Space Programme, unknown even to her Mother. She refers to the involvement of other women in the Soviet Space Programme and recalls how, following her flight, she was welcomed by the world as a heroine.

The remainder describes her life in post-Stalinist times, her commitment to peace, international cultural exchanges etc.

Unfortunately, whatever its other merits, the book does not come across as a well-researched biography but is more in the nature of a tête-à-tête.

COMPUTER SOFTWARE

The Interactive Space Encyclopedia

R. Kerrod, Andromeda Interactive Ltd., 11-15 The Vineyard, Abingdon, Oxfordshire, OX14 3PX, 1993, CD-ROM, £95. Narrated by Patrick Moore.

Recommended system requirements; 16MHz 386 PC or compatible, 1Mb RAM, SVGA (256 kb video RAM), Hard Disc drive with 10 Mb free space, MPC-rated CD-ROM drive, 100% Microsoft-compatible mouse, Soundblaster compatible sound board, MS-DOS 3.3 or higher, MSCDEX2.1 or higher.

The Interactive Space Encyclopedia is a multi-media product which presents the history and technology of space exploration from the 1940s to the present day. The publishers are targeting the encyclopedia at educational establishments and libraries and have stated that it is suitable for use across Key Stages 2,3 and 4 of the UK National Curriculum. Versions are planned for the Archimedes and Macintosh platforms during 1993.

The encyclopedia comes as a compact disc which holds a database of over 3800 photographs and other images, 150 animations and film/video clips, approximately 2 hours of audio (including voice-overs from Patrick Moore) and over 100,000 words of text. The main subjects covered include the Apollo project, the European, Russian and American Space programmes, Satellites, Shuttles, the Solar System, Space People, Probes, Space Stations and the Universe. There are also eight tutorials covering key scientific concepts such as: rockets, light and the scale of the Universe, supported by a dictionary of astronomy and space. Text and pictures on a desired topic can be retrieved from any screen by searching on keywords. Certain words in the text are highlighted: clicking on these with the mouse produces a new screen containing more information (text, image or animation) on the selected word. Text (but not pictures) can be output to a disc file or printer.

For this review, the encyclopedia was installed on a 33 MHz 486 IMB PC-compatible computer which exceeded the MPC-1 standard for multimedia machines. There were problems in running the program. No sound output could be obtained (the soundtrack has not been reviewed), the encyclopedia crashed when the "tour of the disc" option was selected from the opening menu and some images were scrambled. The publishers have stated that the sound fault is a compatibility problem which has been corrected in the copies offered for sale.

In general, the program and the accompanying 32 page Manual appeared very easy to use and it took only a short time to become familiar with the operating procedures. The Manual recommends an SVGA (640 x 480 pixels) video board but most of the static images appeared to be of lesser resolution: although it must be said that viewed from a distance they looked better. The moving images include some short film clips (Astronauts on the Moon, Mission Control for Apollo 11 for example) but are mainly computer animations in 3-D. Events such as the launch of a Saturn V and the ascent of the Apollo Lunar Module from the Moon are shown as computer-generated animations when perfectly good film and videos exist of the real events. The quality of the animations varies. Several animations turned out to be the same unscaled, unlabelled schematic of the planets orbiting the Sun with incorrect relative orbital periods. Some animations (for example the view of the Moon orbiting the Earth) appear to lack sufficient screen resolution to make the point. On the other hand there are many very effective animations such as the illustrations of mirror images, rocket stage separation and the Voyager encounter sequences.

The price (discounted to £75 for schools, colleges and libraries) may appear expensive when compared to ordinary space encyclopedias. For the same price one could have all the colour photographs and text one wanted, printed on glossy paper in a high quality coffee-table type book. However, such a book might not keep its good looks for long if regularly used by many readers, and it could not offer them the animations, film clips, videos, sound track and interactive learning experience which are integral to the Interactive Space Encyclopedia.

Space Adventure

Space Adventure; Knowledge Adventure Inc., 4502 Dyer Street, La Crescenta, CA 91214, USA. 1993. Available as CD-ROM and 3.5" floppy disc versions. Systems Requirements: IBM PC Compatible, CD-ROM drive or 3.5" floppy disc drive, Colour VGA Monitor. Soundblaster and compatibles, AdLib and Covox sound cards supported. Mouse recommended. Printer optional. Needs at least 500Kbytes RAM. Floppy Disc version needs at least 8 Mbytes Hard Disc space. Runs under DOS.

Space Adventure is a multi-media educational product primarily aimed at the younger user but sufficiently stimulating to attract all age groups. It covers a range of Space-related topics including: rockets, human and robotic space exploration, science fiction, solar system, science, and the Universe. There are seventeen video sequences with soundtracks, four animations (including one on continental drift) and a very large number of images supported by narrative descriptions. "Classic" images and videos of the Space Age are included: President Kennedy announcing Apollo, the Apollo 11 Launch, Astronauts on the Moon, Viking and Voyager images and many others.

Space Adventure encourages users to interact with virtually the entire screen, which is divided into a (expandable) window for showing videos, simulations and static images, a window for narrative text, a terrestrial globe and time thermometer for showing the time and place of events, and control icons. The user simply directs a cursor at an area of interest on the screen (be it an image, diagram or text) and clicks the mouse button and the programme switches all the other windows to a related topic and plays an appropriate soundtrack including music, speech and actual sounds where appropriate. This process can be repeated indefinitely. For users who adhere to traditional ways of looking up topics alphabetically, a library index function is provided.

For this review, the CD-ROM version of Space Adventure was installed on a 486 PC compatible running at 33 MHz and conforming to the MPC standard. Installation was straightforward and the programme worked first time without any sound and video compatibility problems being evident. The interface is very easy to use, although the cursor could be made more responsive with advantage. The accompanying 46 page manual is well produced and helpful and it includes a chapter on how parents can encourage children to explore the programme through built-in games. Visually the programme looks attractive and the quality of the images and sound is good: there were no apparent technical errors. On being first invoked, the programme opens with a lively sound and vision sequence of the Apollo 11 launch from Cape Kennedy and it continues to exhibit the same degree of showmanship as each session unfolds.

The charm of Space Adventure is the way in which users are rewarded with attractive sights and sounds on each new enquiry they make so that the most casual enquiry on one topic easily transforms into a prolonged session with the programme. One could have reservations about the efficacy of this method of learning but the end result is certainly very pleasing.

SOCIETY ANNOUNCEMENTS

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.

It may occasionally happen that, for reasons outside its control, the Society has to change the date or topic of a meeting. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always re-check the scheduled meetings in the latest issue.

3 November 1993 — 7 - 8.30 pm

Pluto, Dwarf Planets and Chaos at the Edge of Drkness

Richard L.S. Taylor, Urist Research

The discovery of the trans-Plutonian objects 1992QB$_1$ and 1993FW$_1$ extends the known outer limit of the solar sytem to ~47 AU a region where the temperature is barely ~30K. Since 1991 three other curious outer-solar system bodies have also been found. The similarities between these objects and a number of the previously known small but widely separated outer solar system bodies, including Chiron, Pluto and Triton suggest that they may all have originated in the Kuiper Belt well beyond the orbit of Neptune and have wandered in towards the Sun due to chaotic solar system dynamics, so the Kuiper Belt may be populated by dwarf planets rather than short period comets. Pluto, Triton and these recently discovered bodies thus preserve vital evidence of the primordial composition of the preplanetary nebula and of the formation of the solar system.

A space mission to Pluto through the 2001 launch-window, before the planet re-freeezes for 240 years, is thus essential rather than just desirable. The investigation of other members of this group of objects using low cost micro-spaceprobes constitutes one of the most important solar system space research programmes that can be undertaken over the next 30 years.

1 December 1993 — 7 - 8.30 pm

WHOOSH! Space Propulsion Systems Past, Present and Future

Chris Welch, Kingston University

The underlying aim of any space propulsion system is to generate a force which can be used to change the trajectory of the spacecraft. This force can be generated in many ways. This talk looks at the different forms of space propulsion system that have been suggested in the past, those that are in current use, and those that have been proposed for the future.

LIBRARY

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. The Library will also be open on Saturdays between 10.00 am and 1.30 pm on the following dates:

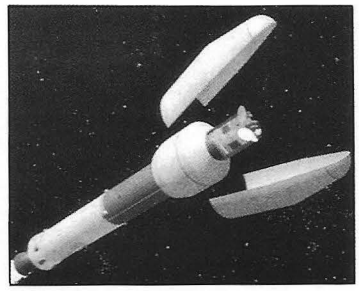
20 November   18 December

Membership cards must be produced.

Bye-Law Revision

In response to representations that it has received, the Council has approved new wording for Bye Law 30(2) as follows:

All other business shall be deemed Special Business. No Special Business on a members' requisition shall be transacted unless notice is given to the Society by the holders of not less than one-twentieth of the total Corporate Membership Voting Rights, not less than six weeks before the date determined as that of the Annual General Meeting.



Name the Sats Competition Winners

Lucky readers to whom a prize of a crystal glass beaker will shortly be dispatched are:

J. Gray	UK
M. Howard	New Zealand
D.K. Whittock	France

The answers to the eight clues were: Spot, Astra, Telstar, Posat, Insat, Solidaridad, Healthsat and Asap.

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The following complete volumes of ***Journal of the British Interplanetary Society (JBIS)*** are available from the Society in limited numbers.

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1954	13 *	6	24	1978	31	12	30
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The International Magazine of Space and Astronautics

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Lunar Base Siting

'Lunar Landing' Competition

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CONTENTS

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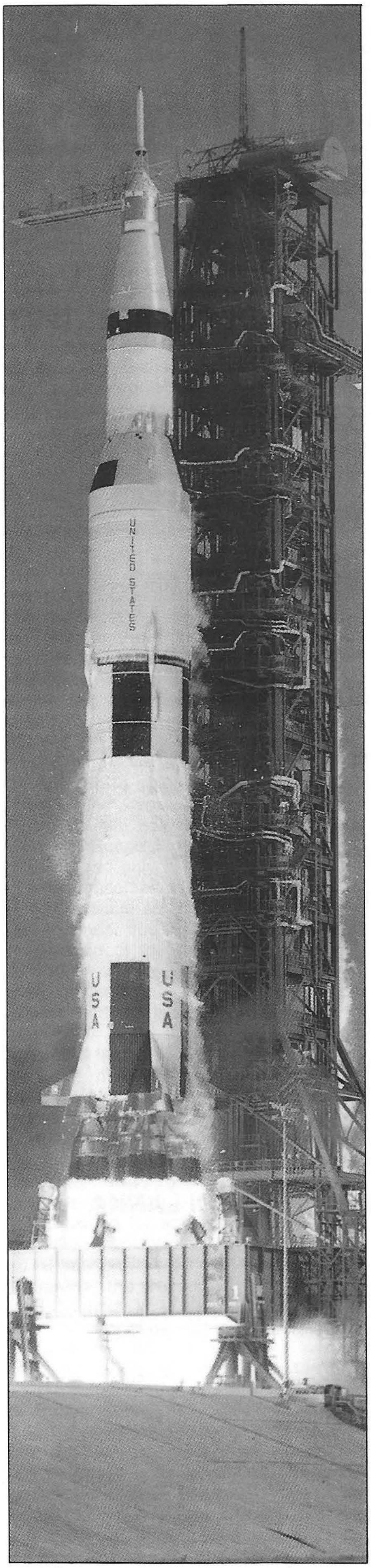
Front Cover: A lunar rover explores near the Moon's north pole in the 21st century. *P.G. Goodwin BA, FBIS*

Return to the
A Case for Earth

A heavy lift launch vehicle is the linchpin of any plan for returning men to the Moon. Recent studies defining manned SEI lunar missions have focused on National Launch System and Saturn V derivatives as a basis for mission planning [1]. The cancellation of the NLS program in the fall of 1992 effectively eliminated that vehicle from consideration for SEI planning. This paper will focus on a more viable alternative: reviving the Saturn V launch vehicle; or more specifically within the context of this article, using the first two Saturn V stages, the S-IC and the S-II, to support a mission architecture based on the Earth Orbit Rendezvous (EOR) mode.

THOMAS J. FRIELING
Bainbridge College



The 363-foot-high Saturn V vehicle lifts off for the first manned lunar landing on the Apollo 11 mission, July 16, 1969. *NASA*

Introduction

EOR was one of three contending mission modes for the Apollo lunar missions, but was rejected in favour of Lunar Orbit Rendezvous. At the time LOR was an attractive mode because it maximized the payload that could be delivered to the lunar surface and allowed the entire mission to be launched on a single launch vehicle.

In 1962 the nation had no extant heavy lift launch vehicle and no experience in rendezvous and docking. However, in the intervening thirty years NASA has accumulated a wealth of experience in launch and space operations, experience that justifies taking a second look at the EOR mode for SEI missions. Flying the Saturn V in a two-stage-to-orbit configuration will permit reuse of the S-II stage as a Trans Lunar Injection stage. Central to this proposal is a low Earth orbital Transportation Node at which the S-II stage can be berthed to await refuelling and the arrival of the lunar crew and cargo spacecraft.

Heavy Lift Launch Vehicle

Twenty-five years after its first flight, the Saturn V is still by far the most powerful launch vehicle ever brought to operational status in the West. It flew thirteen consecutive successful missions before it was retired in 1973. It is still a suitable launch vehicle choice for supporting SEI lunar missions and is eminently capable of being brought back into production.

In addition to the wealth of operational experience gained in the 1960's and 70's developing and launching the Saturn V, a great deal of infrastructure remains to facilitate re-opening production lines. Capitalizing on this infrastructure will lower start up cost and shorten development times for regaining the nation's heavy lift capability, important considerations in the current stringent budgetary climate.

Among the extant Saturn hardware available are two complete Saturn V flight articles complete with F-1 and J-2 engines--AS 514 at the Johnson Space Center and AS 515 at the Michoud Assembly Facility. In addition, two of the four original ground test articles are available--AS 500-D, the Dynamic Test Vehicle, at the Marshall Space Flight Center; and AS 500-T, the All Systems Test Vehicle, at the Kennedy Space Center [2]. Although these full-scale flight and ground test vehicles are now considered museum pieces, they are available to provide early pathfinder experience for facilities checkout and crew training.

A 1990's version of the Saturn V will also benefit from upgrades pursued during the original production run of the F-1 and J-2 engines that were designed to increase their thrust. The upgrades to the F-1A were demonstrated on two engines that were static fired at 1,800,000 pounds of thrust, a significant improvement over the 1,500,000 pounds of thrust for the original F-1.

Similarly, the J-2S upgrade was tested on six engines in static firings at 265,000 pounds of thrust, compared to 200,000 for original J-2 flight articles.

In addition to the ten F-1 and twelve J-2 engines on outside display at JSC and Michoud, a total of five F-1 and four J-2 engines remain in bonded storage at Michoud and are available for early pathfinder experience for manufacture and static testing. Static test stands are available for re-activation or re-conversion at both MSFC and at the Stennis Space Center to support both single engine and full stage testing [3].

In addition to this available hardware and ground support facilities, F-1A and J-2S production restart will benefit from Rocketdyne's Knowledge Retention Program implemented in 1969 to document engine production and to assist in any restart. Documentation on both engines span over 40 volumes covering every aspect of manufacture. Additionally, over 300 current or former Rocketdyne personnel with F-1 engine experience have been identified as being available to support F-1A production. Rocketdyne estimates that it will cost $1.5 m to restart F-1A production with a unit cost of $16 m [4].

The original F-1 and J-2 tooling was scrapped at the completion of the pro-

Moon to Stay
Orbit Rendezvous

gram in the 1970's; however, Rocketdyne's recent experience in restarting production lines for the Atlas and Delta programs demonstrates that out-of-production hardware can be brought back into production with new tooling. Indeed, Rocketdyne concluded that old tooling was not always cost effective and that new tooling allowed for complete process optimization.

State of the art manufacturing technologies including CAD/CAM databases and Total Quality Management techniques can be employed to lower the cost of manufacture while maintaining high standards. Additionally, new composite materials and aluminum-lithium alloys can reduce the weight of the S-IC and S-II stages. Using composites in place of the original aluminum for the forward skirt, intertank and interstage structures and the S-IC fins and engine fairings will produce a lighter weight, higher performance Saturn V.

Given this wealth of extant hardware and prior experience with manufacture, an uprated Saturn V could be available for flight test in a relatively short period of time if configuration changes to the vehicle are kept to a minimum. For this reason, no liquid rocket booster strap-ons, stretch versions, or recovery and reuse of S-IC stages are postulated in this scenario, although such improvements should be considered later on in the programme as payload and cost requirements dictate. The emphasis here is to maximize use of proven technologies and to wed them to state of the art manufacturing techniques to reduce development costs and manufacturing time.

Given adequate funding it is reasonable to expect that flight hardware could be ready for launch in five or six years from programme approval, or about the same amount of time it originally took to go from first contract to first launch in the 60's [5].

In this proposed mission scenario, the Saturn V will fly in a two-stage-to-orbit configuration, much as it did on its last mission when live S-IC and S-II stages placed the Skylab space station into orbit along with the spent S-II stage. This two-stage-plus-payload configuration will eliminate the need for the Saturn's third stage, the S-IVB, or a new TLI stage. Refuelling the S-II stage at an LEO Transportation Node will provide the capability to send a 275 ton payload to the Moon, a significant improvement over the current baseline of 95 tons for the NLS-based TLI stage. Furthermore, the S-II is capable of sending both the Manned Lander and Habitat vehicles in one manoeuvre.

Launch Facilities

Most of the launch facilities that supported Saturn V operations at KSC were converted for use in the Shuttle program during the 1970s. However, not all Saturn support is gone; much can be re-converted or otherwise adapted to permit support of both Saturn and Shuttle operations at Launch Complex 39.

Three High Bay areas of the Vehicle Assembly Building will require modifications to restore their capability to stack and process Saturn Vs, while leaving one High Bay available for Shuttle operations.

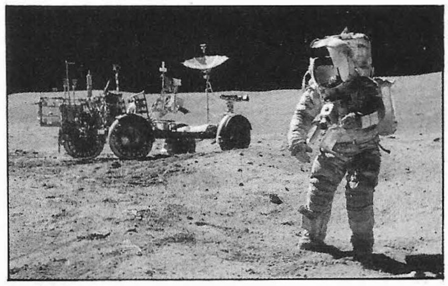
The crawler transporters from the Apollo Program are still in service moving the Shuttles to the launch pads. However, new Mobile Launch Platforms which attached Launch Umbilical Towers will be required to replace the platforms converted for Shuttle use. The accompanying Mobile Service Structures will also need to be reconstructed, since the Apollo MSS was scrapped. Since commonality with the original Saturn V configuration should be maximized, only minor changes will be needed in the LUT/MSS structures. Payloads will replace the S-IVB stage, so umbilical and swing arm changes will be restricted to that level.

Pads 39A and B will need only minor modifications to serve as dual use Saturn V/Shuttle pads, much in the same manner as the proposed conversion to support NLS activities [6]. A third pad will be needed to support the multiple Saturn V launches required for the EOR mission mode. The site originally planned for Pad C in the 1960s is still available at KSC.

A new Payload Encapsulation Facility will process the Lunar Habitat and Manned Lander vehicles, replacing the Operations and Checkout Building for this purpose. The payloads will be delivered to the VAB completely processed and encased in a launch shroud for stacking and transport to the pad.

Spacecraft

For the purposes of this discussion, the lunar spacecraft are based on the Lunar Habitat and Manned Lander vehicles as defined in NASA's First Lunar Outpost studies. Both vehicles employ a common lander stage utilizing LH_2/LOX propellants and four RL-10 engines modified for throttling. A Space Station Habitation module serves as the basis for the Habitat vehicle which contains all the life support consumables for the crew's stay as well as workstations, a limited



Apollo signalled the opening of the lunar frontier. *NASA*

amount of science payload, and an airlock for lunar surface activities. The Habitat vehicle is designed for an automated landing in advance of the Manned Lander. Once on the surface, the Habitat will self-deploy solar panels to generate electricity during the lunar day. Fuel cells will provide power for the two-week long lunar nights.

The Manned Lander, employs an Apollo-style expendable capsule capable of carrying a crew of four with an ascent stage using storable propellants for return to Earth on a direct ascent trajectory [7]. The Lander will also contain the lunar rover and the majority of the science payloads such as a prototype radio and optical telescopes and technology demonstration equipment to utilize indigenous materials, especially the extraction of oxygen from the lunar regolith.

Weight estimates for the FLO payloads under current NASA planning total approximately 94 tons each post-TLI or 188 tons for the entire mission. However, by using the more capable S-II stage as the TLI stage, the payloads can be dramatically increased to 275 tons with both spacecraft being sent on a trans-lunar trajectory together on a single S-II TLI stage as opposed to the FLO mission profile which uses two NLS-based TLI stages.

Employing the S-II as the TLI stage thus will allow both spacecraft to be sized-up to carry more scientific payloads and associated equipment down to the lunar surface and to provide additional consumables to extend crew surface activities beyond the current 45 day baseline mission.

LEO Transportation Node

The First Lunar Outpost reference spacecraft [8] weigh approximately 205,000 pounds each post-TLI under current planning. However, by adopting an EOR mission mode and using a refuelled S-II stage as the TLI stage, the spacecraft may be sized up to 275,000 pounds each post-TLI to allow for longer lunar stay times and/or more science payloads delivered to the lunar surface.

The key to using the S-II as a TLI stage is a low Earth orbital Transportation Node. The Node will provide a no-frills three-axis stabilized platform, electricity, telerobotic arms, and

cryogenic storage and transfer capabilities needed to support the S-II TLI stage while the spacecraft and LH_2/Lox needed to refuel the S-II are delivered by separate Saturn V launches.

Employing Space Station and Shuttle structural elements will maximize commonality with hardware already in production to keep development costs down. The backbone of the Node platform is a length of Space Station trusswork, to which will be attached the various elements needed to accomplish the berthing and refuelling of the S-II. Solar panels derived from Space Station Freedom will provide electricity. A reaction control system based on Shuttle Orbital Manoeuvring System technology supplemented with control movement gyros will provide stabilization and re-boost capability [9].

Remote Manipulator Arms adapted from the Shuttle will grapple spacecraft and tankers delivering LH_2 and LOX and berth them at the attach points along the trusswork. A cryogenic storage tank will provide storage of LH_2 and LOX prior to transfer to the S-II. To allow for a certain amount of boil-off, the storage tank, based on S-II tankage, will require a ten to twenty per cent stretch to provide the necessary volume. The tank will be topped by a deployable solar shade to minimize boiloff of LH_2/LOX and also to protect the tank from orbital debris.

Launched by a single Saturn V with deployment assistance provided by a Shuttle crew if necessary, the Node is assumed to be a highly automated, man-tended facility with command and control electronics modules for ground control of Node operations through the TDRSS. Between executing its primary function in supporting SEI lunar missions, the Node will remain available as a stabilized platform for automated materials processing modules like Space Industries Industrial Space Facility or other payloads that could benefit from lengthy exposures to the space environment.

Revisits by the Shuttle for periodic maintenance and resupply of consumables (e.g., hydrazine for the OMS pods) will enable the Node to support multiple SEI missions over several decades.

Putting this infrastructure together will require a significant amount of effort and funding. The LEO Node is a major programme in itself. However the capabilities of the resulting infrastructure will provide a durable space-based facility for supporting extended lunar exploration, embryonic lunar bases, and eventually, manned expeditions to Mars. Indeed, this proposed mission profile develops five of the fourteen areas of technological emphasis identified by the Stafford Synthesis Group as being essential for support of SEI missions:

1. a heavy lift launch vehicle,
2. cryogenic transfer and long term storage,
3. automated rendezvous and docking of large masses,
4. telerobotics, and
5. light structural materials and fabrication [10].

Early technology demonstrations using subscale Node components can be made on Shuttle flights to verify operations such as fuel storage and transfer.

Operations

Initial SEI lunar missions employing this EOR mode will begin with the launch of the FLO Habitat/Lander vehicle atop the uprated Saturn V from Pad 39A. The S-II stage, modified for its role as the TLI stage, will place itself and the payload into orbit and will conduct an automated rendezvous with the Node where it will be grappled by the RMS arms and berthed on the Node truss. The Habitat/Lander vehicle will be powered down and the S-II's residual LH_2/LOX will be transferred to the storage tank.

The Manned Lander vehicle will then be rolled out to pad 39A to join two tanker Saturn Vs on Pads 39B and 39C. These two vehicles will consist of live S-IC and S-II stages topped by LH_2/LOX tankers based on S-II tankage. The launch sequence continues with the launches of the two tanker Saturns, which will rendezvous and dock at the Node where their cryogenic propellants also will be transferred to the storage tank to reduce boiloff.

With the propellants delivered by the tankers, the fourth and final Saturn V will be launched from Pad 39A to place the Manned Lander vehicle and four person crew into orbit. The crew will rendezvous and dock with the Node where the S-II's residual propellants again will be transferred to the Node's storage tank.

The RMS arm will berth the Manned Lander vehicle atop the S-II, completing the build up of the stack: the S-II TLI stage with Habitat/Lander vehicle, topped by the Manned Lander vehicle. The LH_2/LOX then will be transferred from the storage tank to refuel the S-II TLI stage and the entire 160 foot long stack will separate from the Node and initiate the Trans Lunar Injection burn, delivering its 550,000 pound payloads to the Moon.

The logistics of this mission mode may seem overly complicated at first glance; however, the proposed launch sequence is designed to provide a great deal of flexibility to allow the mission to recover from a launch failure at any point in the sequence. A failure on launch one will place the mission on hold until a backup Habitat/Lander vehicle and Saturn V are available. Failure of launch two or three will allow the Habitat/Lander and already delivered LH_2/LOX to be stored on-orbit until a replacement Saturn V and tanker are readied. And failure of launch four will permit the Habitat/Lander vehicle to be sent on to the lunar surface to await the launch of a replacement Manned Lander. These are worst case scenarios--the Saturn V has proven to be a highly reliable launch vehicle with an excellent record for on-time launches. Indeed, of the thirteen consecutive successful Saturn V launches, not a single countdown was scrubbed and only two experienced minor delays, one of which was weather-related.

Mission success and flexibility can be further enhanced by separating the payloads from the Habitat/Lander vehicle. By locating all of the major scientific payloads and the lunar rover

Correspondence

To the Moon

Sir, From all that I read in recent issues of ***Spaceflight*** about an outpost on the Moon, it seems to me that:

- A return to the Moon needs an investment of several billion dollars;
- The present economic situation does not lead governments to think about it very seriously;
- Progress comes through an increasing involvement in international space (and other international cooperations);
- Considering all the countries with a space capability (USA, CIS, Europe, Japan, India and China), we have enough knowledge, experience and designed hardware to begin operations to return to the Moon.

The conclusion is immediate: it is now possible to have this outpost; the only problem is to make an agreement between all the partners.

With reference to the General Dynamics ELA Programme (***Spaceflight***, May 1993), I would suggest the following changes:

- Fuel tanks for LEV to be carried to orbit by a different launcher, to avoid problems with the shuttle;
- The LEV to be similar to an Apollo Lunar Module and not designed to enter the Earth's atmosphere. In this way it would be lighter, recoverable by the shuttle and reusable. Astronauts would return home in the shuttle too.

I think we must be very clear that the goal is to install an outpost on the Moon. Given that, arguments like this "being little more than a bigger brother of Apollo" become nonsense.

The most important thing is to begin: once man has returned there he will never again stop going. The key step is the first step, and this could be taken relatively cheaply and within a few years with existing equipment.

JUAN OTEGUI POLIT
Spain

in the Manned Lander, which has an independent stay time of several days, scientific payloads can still be emplaced on the lunar surface and some useful geological field work can be accomplished by the crew even if the Habitat/Lander vehicle fails to land successfully.

Scheduling Logistics

The forty-five day FLO baseline mission, expanded to an even longer stay time in this scenario, is over three and a half times longer than the entire lunar surface stay time accumulated by all six Apollo landings combined. Moreover, the FLO crew is twice as large as Apollo's. Given this quantum leap in lunar surface exploration capability, serious consideration must be given to the logistics of planning and scheduling exploration activities. Mission planners will find it a challenge to schedule profitably surface activities so as to make optimum use of the crew's valuable time. These scheduling concerns will be especially true during the 14-day long lunar night.

Additionally, the drama that man's return to the Moon is likely to generate (at least initially) among the public and in the press means that public attention and media scrutiny will once again be focused on the missions. The average taxpayer must be convinced that the science and technology work being conducted on the lunar surface are in fact a good buy for the large sums of federal money being spent on what amounts to a highly visible national research laboratory.

Support for the Apollo missions quickly evaporated, partly because public expectations were focused primarily on getting to the Moon. Once the first landing was accomplished, the public interest in return visits waned because of the widely held impression that "there was nothing more to be done" on the Moon and that return visits were a waste of money [11]. The fact that half of all of the manned Apollo/Saturn V missions were launched within a one year period reinforced the public attitude that we were going in haste.

Mission planning for the much longer SEI lunar missions must take into account this past experience, lest it fall victim to the same public apathy and backlash that terminated the first phase of lunar exploration.

To avoid even the appearance of going just for the sake of going, a judiciously paced set of clearly defined missions must be articulated at the outset of the programme.

A programme likely to maintain public support over the long term is one in which a set of ten missions are carefully planned and launched at two and a half to three year intervals. They typically will deploy highly visible payloads such as a lunar observatory that will return clearly understandable results.

The enormous amounts of data and samples returned by a crew of four working for forty five or more days on the Moon is enough reason alone to space the missions far enough apart so that lessons learned from Mission One will be fully integrated into planning for Mission Two.

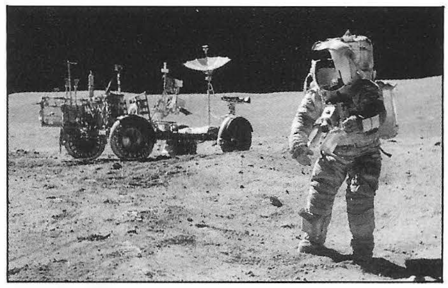
In short, NASA must take the advice offered it more than twenty-five years ago when the agency solicited inputs from the scientific community and was told: "It is clearly desirable to schedule flight missions to provide adequate time between missions to react to the findings of one mission by modifying experiments for a later mission" [12].

A programme of ten SEI lunar missions conducted over a twenty-five to thirty year period will provide a stable foundation from which US aerospace industries can transition from Defense work into the post-Cold War economic era. Additionally, a long term commitment to a programme of manned lunar exploration will stimulate interest among today's students in pursuing science, engineering, and technical careers, precisely the types of jobs and skills needed to assure US economic leadership in the 21st century.

Conclusions

SEI lunar missions utilizing the EOR mode will protect against the loss of large payloads to a single launch vehicle failure. Although the EOR mode limits lunar missions to a once-per-month launch window (dictated by lighting angles at the landing site) and requires multiple launches, the Saturn V is a highly reliable launcher with an excellent record for on-time launches. Using an uprated Saturn V heavy lift launch vehicle will lower initial start up funding for the lunar program if modifications are kept to a minimum. Launch vehicle performance enhancements such as F-1A LRBs may be pursued later on in the programme as payload requirements dictate. Additionally, recovery and reuse of the S-IC stage will serve to reduce by as much as two-thirds the number of stages needed over the life of the programme [13].

The LEO Transportation Node required to berth and refuel the S-II TLI stage represents the biggest technological challenge presented in this scenario, but promises the most gain in terms of performance and in development of the technologies and operational experience required for extended manned lunar and Mars exploration. EOR missions utilizing the Node will be capable of landing at sites far north or south of the lunar equator, thus eliminating a major limitation of the Apollo LOR mode. Early technology demonstrations in areas such as storage and transfer of cryogenics



could be obtained using subscale components launched on the Shuttle.

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Biography

Thomas J. Frieling is Library Director at Bainbridge College, Georgia. He has contributed numerous articles on space policy and space history to magazines such as *Technology Review*, *Astronomy*, *Space World*, and *Aviation Week and Space Technology* and is a book reviewer of space-related titles for *Library Journal*. A long-time observer of the US space program, he is currently conducting research into the Apollo Applications Program and the Saturn launch vehicles. He is a member of the American Institute of Aeronautics and Astronautics.

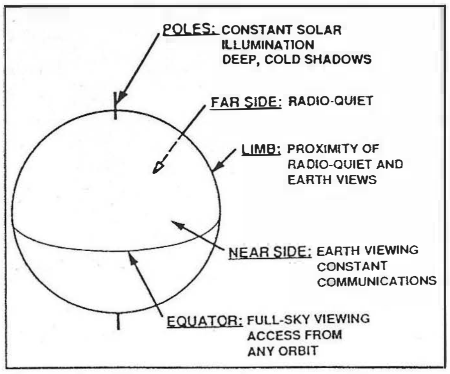

Fig. 1 Considerations for lunar base sites.

Lunar Base

Speculation with regard to a permanent lunar base has been with us since Robert Goddard was working on the first liquid-fuelled rockets in the 1920's. With the infusion of data from the Apollo Moon flights, a once speculative area of space exploration has become an exciting possibility. A Moon base is not only a very real possibility, but is probably a critical element in the continuation of our piloted space programme. This article, originally drafted by World Space Foundation volunteers in conjunction with various academic and research groups, examines some of the strategies involved in selecting an appropriate site for such a lunar base. Site selection involves a number of complex variables, including raw materials for possible rocket propellant generation, hot and cold cycles, view of the sky (for astronomical considerations, among others), geological makeup of the region, and more. This article summarizes the key base siting considerations and suggests some alternatives. Availability of specific resources, including energy and certain minerals, is critical to success.

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Introduction

Of nineteen lunar surface sites explored to date, a diversity of features and characteristics have been examined. If the first lunar "resource" is information, then the utility of a locale for the in-situ and observational sciences will rank high. Early site selection will be governed by safety, economy, and immediate utility of the resources already known. Later site selections will depend on new knowledge of all types of resources (Fig. 1).

Present discussion of base sites is driven most strongly by the scientific community with consideration to engineering feasibility and eventual resource utilization. Lunar geology, lunar geophysics and other disciplines concerning the Moon and its environs (selenology) dominate one branch of scientific utilization, while use of the Moon as a platform for astronomy, space physics, Earth and solar observations dominates the other branch. Overlying any discussion of site selection for these uses are the suitability of local terrain, viewing of the Sun, Earth and heavens, availability of energy and heat rejection paths, and local material resources.

One of the earliest discussions of lunar base location was put forth in 1920 by Robert H. Goddard, a pioneer in American rocketry. He noted, "The best location on the Moon would be at the north or south pole with the [propellant] liquefier in a crater, from which the water of crystallization may not have evaporated, and with the [solar] power plant on a summit constantly exposed to the Sun. Adequate protection should, of course, be made against meteors, by covering the essential parts of the apparatus with rock." (see p. 405, upper picture). Many would still credit him with a valid conclusion, even though geologists will offer different explanations if volatiles are found at the poles. Recent ground-based radar indications of the possibility of ice near Mercury's poles weakens some arguments against the possibility of lunar polar ice by suggesting that solar wind erosion may be less important than proposed in limiting ice buildup.

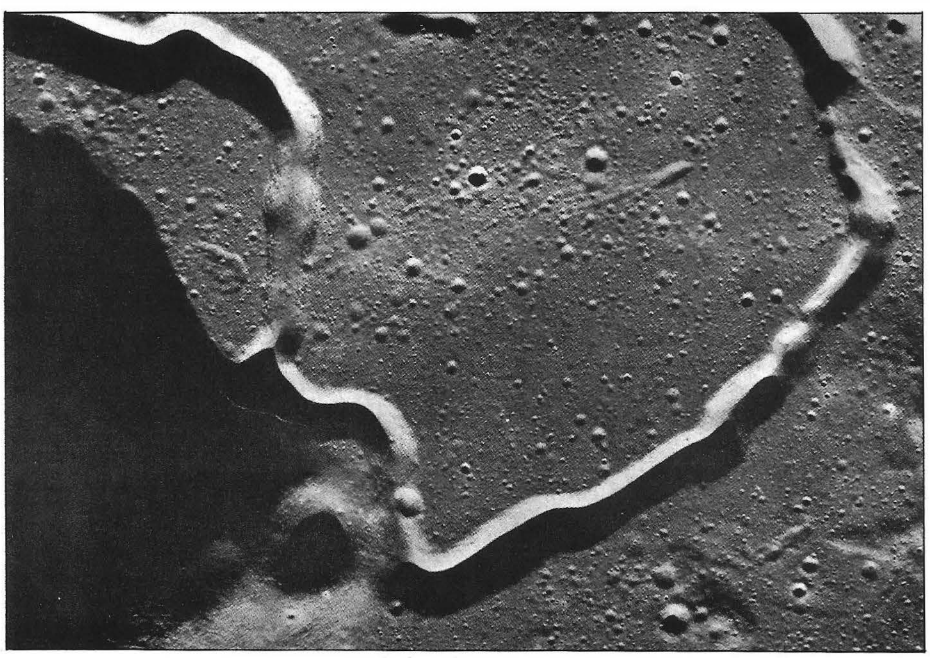
Early locales with diverse materials are likely to outrank locales with the highest concentration of a single desired substance. The exception may be any site with a concentration of hydrogen or carbon in some form, such as ices or subsurface gas reservoirs. Scarcity of these types of reducing agents has come to be the dominant limitation in most discussions of lunar resource utilization.

Geologists want to sample and record a diversity of terrain representing the major geologic phases of the Moon's formation and evolution. Mare and highland sampling at many sites is considered essential, with age diversity important.

Energy is another resource, certainly for surface operations, and perhaps even for export. If nuclear power is unavailable at the required levels, energy storage equipment for the 14-day night is important. High crater rims and peaks near both poles may offer near-constant solar illumination, and modest towers at these locations certainly will, but a thorough lighting survey has yet to be conducted to pin down the best locations.

Any location on the Moon would do for a partial gravity test facility for life

Fig. 2 Sinuous Hadley Rille was the landing site for Apollo 15, located near the bottom-centre edge of this photograph. North is to the right, the Apennines lay to the East, just off the bottom edge. Although there may be more optimal lunar base sites, Hadley Rille would be a reasonable choice.



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Siting

sciences investigations. For photosensitive organisms, polar locations could offer piped-in sunlight on any day-night cycle researchers might choose.

Flight mechanics into and out of a base site can be an important consideration. Equatorial and polar sites are favoured for their near-constant accessibility.

Slopes and terrain features can be resources themselves. Slopes offer favoured illumination and shadowing, while craters offer natural depressions for astronomical instruments, barriers to lander exhaust-driven debris, reactor shields and other uses. Elevation differences also figure into some energy storage schemes.

Surface mobility will influence site selection by dictating the range of accessibility from a core base site. Subsidiary sites can serve a variety of specialized purposes, such as mining where different ores are accessible. Sensitive astronomical instruments will need to be away from frequent surface activities. After accounting for the diffraction of the signals of these activities, we find that if a main base is located near the limb as viewed from Earth (i.e., 90 degrees longitude), a subsidiary site at about 101 degrees east or west longitude affords sufficient radio isolation from Earth at the limits of the Moon's east-west libration (or "wobble").

If we had to choose a site today and be certain of a workable, if not at all optimal locale, the Apollo 15 landing site at Hadley Rille (fig. 2) would be a reasonable choice. But we can already see superior sites, though we do not know precisely where it is safe to put the base's first landers down. Virtually all investigators agree on the wisdom of a lunar polar orbiter with suitable composition-measuring instruments plus imaging. Surface rovers may be advisable at "finalist" sites, while teleoperated (remotely controlled) rovers will surely play an important role in exploration from any base site. Early missions could even be used to build a cache of some useful product, such as oxygen, for use by later human explorers.

As important as further lunar reconnaissance is, terrestrial development and testing of alternative resource extraction processes is essential. Operation of one or more lunar base analogs (as in ground-based simulations) would offer invaluable experience at a fraction of the cost of making mistakes on the Moon. Determination of the most workable and economical resource extraction processes will influence any resource-driven site selection.

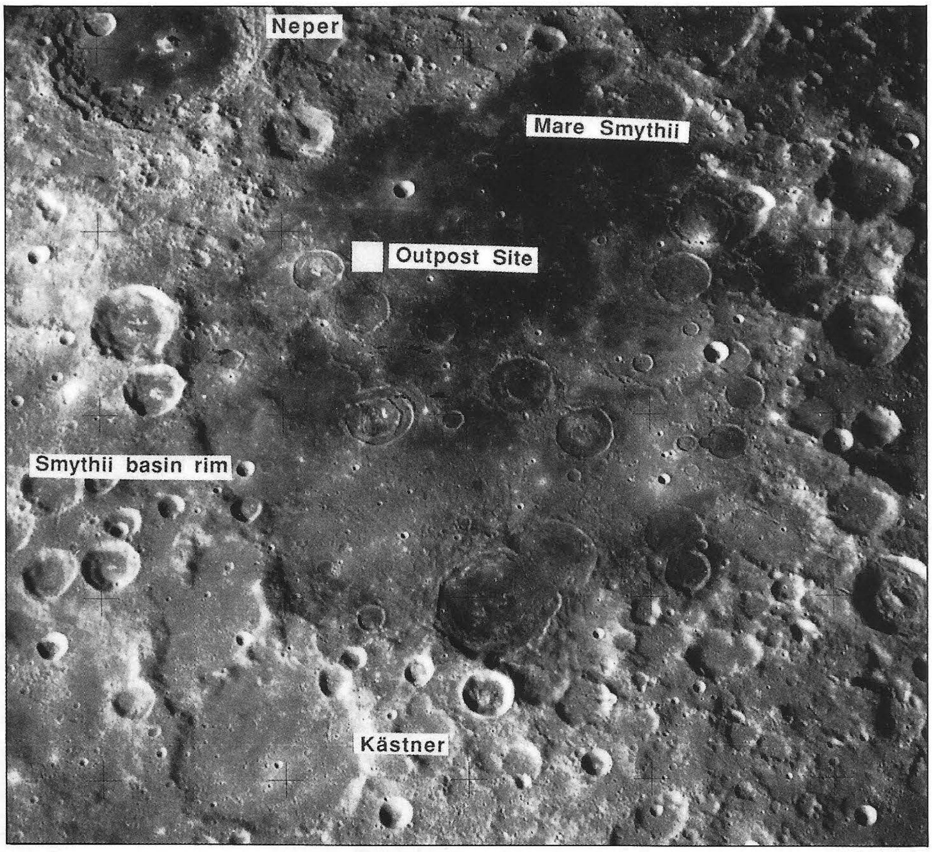


Fig. 3 Lunar outpost site near Mare Smythii.

Base Selection Criteria

The search for potential lunar base sites is a complex undertaking. There are widely dispersed lunar sites of interest for known and potential resources, selenology (the science of the Moon and its environs), and observatories. Important characteristics include certain geological and topographic features, local mineral and rock composition, solar illumination, view of Earth and the celestial sphere, and soil engineering properties (including usability as a construction material, etc.). Space vehicle arrival and departure trajectories favor equatorial and polar sites. Over time, base sites will be developed serving different purposes. Information may be the initial lunar "resource," in the form of observational and on-site research. Resource-driven sites may see the fastest growth during early decades of lunar development, but selection of initial sites is likely to be driven by suitability for a combination of activities.

Only equatorial locations offer nearly all-sky views for astronomy, while most of the far side offers radio isolation. Such isolation could offer radio astronomers a view of the universe unfettered by television broadcasts and a host of other terrestrial interference. A base in Mare Smythii (Fig.3) with subsidiary outposts would be favourable for a variety of purposes, and would preserve a broad resource flexibility. Discovery of accessible volatiles (substances which are easily vaporized, such as methane, water and carbon dioxide, which often turn out to be useful for sustaining life and making rocket propellants), in the form of polar permafrost, subsurface gas reservoirs, or comet impact remnants, would dramatically increase the attractiveness of such a site from a logistical support and selenological point of view. For example, a ready source of water ice would allow the manufacture of hydrogen and oxygen for the trip home or to other destinations (It should be noted that no reliable evidence of such volatiles exists). With the availability of near-constant sunlight for power generation and permanently shadowed areas at cryogenic temperatures, polar sites require substantially less Earth-launched mass and lower equipment complexity for an initial base. Polar sites are, however, scientifically less interesting with their limited view of the sky and absence of important types of terrain common at lower latitudes.

Reliable evidence exists for areas of certain mineral concentrations, such as ilmenite, which could form a feedstock for some proposed resource extraction schemes. In addition to being a source for oxygen and iron, ilmenite (composed of iron, titanium, and oxygen) harbors higher concentrations of solar wind-implanted hydrogen, carbon, nitrogen and helium. These elements were apparently exhausted from the Moon during its formation and evolution, but minor concentrations have collected out of the

tenuous plasma discharged from the Sun and driven across the Solar System as the Solar wind. New data from a lunar polar orbiter are essential for the most informed site selection. Data from the first Galileo flyby have already revealed previously unknown features and will aid surface mineralogical characterization.

The Present Understanding of the Moon

The last unmapped region of the Moon, near the south pole, was photographed during the December 8, 1990 Galileo flyby, but there is a great deal more that would be helpful to know in selecting base sites. From Ranger through Apollo the trend has been to open up mission constraints to afford better scientific opportunities. Apollo 11 was sent to a flat mare region for safety. In contrast, the Apollo 17 site was selected for its geological diversity within a small area (Fig.4).

The last three Apollos carried a set of orbital instruments designed to map the surface at fine resolution and infer its composition, but near-equatorial orbits limited their coverage to less than 20% of the Moon. Crude geologic maps of the entire surface have been constructed from the best available data of all types.

Information needed for selecting the best base sites depends on the objectives of these bases. However, some kinds of data are required for nearly any base. Local topography is an obvious need, and most investigators agree that, except for the immediate vicinity of the Apollo sites, present information is inadequate. Even without elevation data, positions of features are typically uncertain by 1-3 km on the near side, by 3-6 km poleward of 65 degrees latitude, and by 3-15 km on the far side (It is important to remember, though, that terrestrial explorers seldom knew their locations a fraction as accurately).

An orbiting laser altimeter and a metric camera system offer the preferred means for improving lunar topographic maps. Knowing topographic obstacles is essential for safe approach from and departure to orbit, as well as for designing solar power and thermal radiation installations for a specific site. Spatial resolution of 1 meter or better is preferred to certify landing sites.

The next most important new information probably concerns the subsurface mechanical properties, to a depth of at least a meter, that affect digging, foundation-building and other preparations at any specific site. Where mining is contemplated, such information is important to a greater depth. Though the lunar surface has been somewhat homogenized by impacts, it does vary in state of compaction, grain size distribution, size of embedded rocks and other mechanical properties.

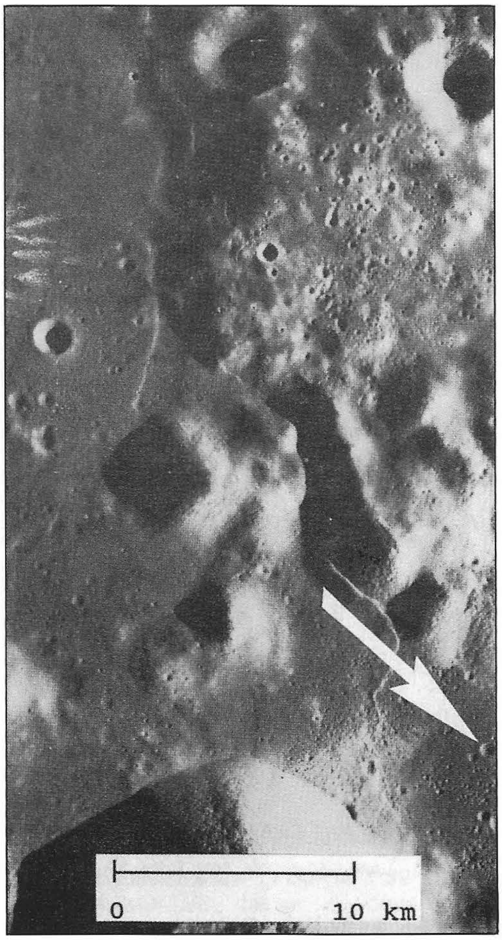


Fig. 4 Arrow indicates the Apollo 17 landing site near a variety of geologically interesting formations.

While compositional properties may be less important than local topography and soil mechanics during the earliest lunar operations, composition will dominate once resource development begins. Compositional information is therefore highly desirable even before choosing the first base site.

Multispectral remote sensing from orbit provides needed regional data, after which surface traverses are best for detailing the most promising locales. Long range rovers teleoperated from Earth carrying imaging, geochemical and geophysical instruments, would be suitable for both scientific and resource site reconnaissance. Use of these rovers could continue during base build-up.

Depending on a short list of candidate sites, different kinds of local information may be useful for selecting a final site. For a polar site, an orbiter with altimetry and metric imaging could perform a survey of varying surface lighting conditions for siting solar power generators, radiators and instruments. In the event an orbiter detects indications of volatiles near one of the poles, surface exploration may be required for precise location. In a similar fashion, it could prove useful to explore volcanic ar-

Surface Transportation

Lunar Outpost **is the title of a publication that depicts concepts developed during the Lunar Base Systems Study undertaken by the Advanced Programs Office, in the Engineering Directorate of the Johnson Space Center, in 1986-88. It was recognised at the time that the spacecraft concepts presented may not be the ones that will eventually fly and that some of the elements described may not even be built. Its purpose was not to present a preferred path or "road map" to the Moon, but to enlighten the reader on the needs of lunar exploration and development, and to challenge the reader to formulate new ideas and concepts. We present here the section on 'Surface Transportation'.**

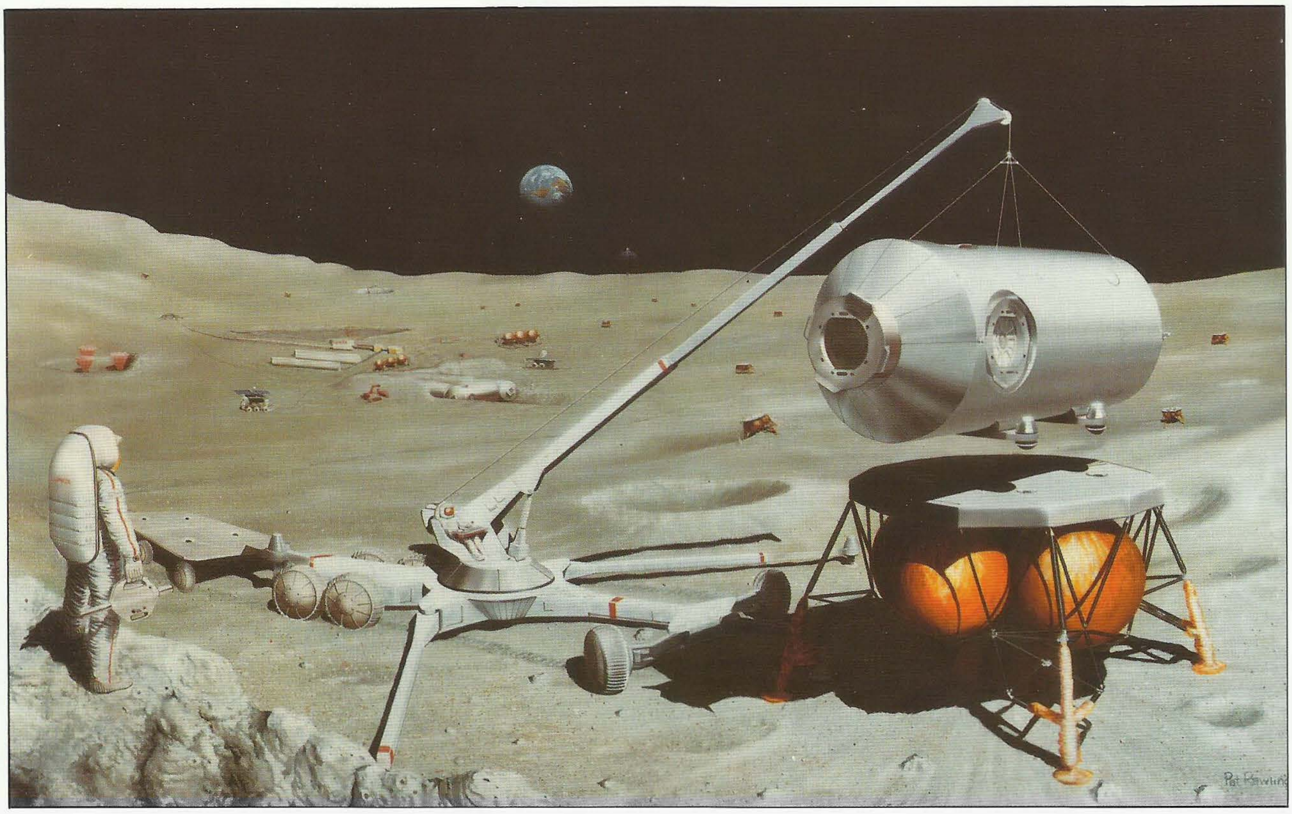
Lunar surface transportation is designed to move people and equipment to accomplish local objectives and perform long distance missions including the mapping and surveying of future mining and resource sites. Other construction tasks, such as excavation or large equipment assembly, will be accomplished by specially designed construction equipment.

The operating conditions for surface vehicles will be very different from terrestrial travel conditions. The Moon has one-sixth the gravity of Earth, practically zero atmosphere, extreme temperature swings (102 K to 384 K, or -250°F to +257°F, at the Apollo 17 site), and almost no magnetic field to provide protection from radiation. The vehicles required for lunar operation must not only survive this environment but do so over many years.

When humans return to the Moon, the surface vehicles will be designed with the help of past experience - Apollo missions 11, 12 and 14 through 17, and the unmanned Soviet Lunokhod 1.

Two types of transportation vehicle will be required during the buildup phase of the lunar outpost: an unpressurised rover for local transportation, and a pressurised vehicle for long-range travel.

The local rover, LOTRAN (local transportation vehicle, unpressurised), is designed for a range of 100 km with a maximum speed of 15 km/h. Its passive suspension in the form of metal-elastic wheels simplifies the design by reducing the number of moving parts and opportunities for failure. The vehicle is fully articulated at two joints, allowing for obstacle avoidance and/or negotiation. It can carry two crewmembers plus 850 kg of



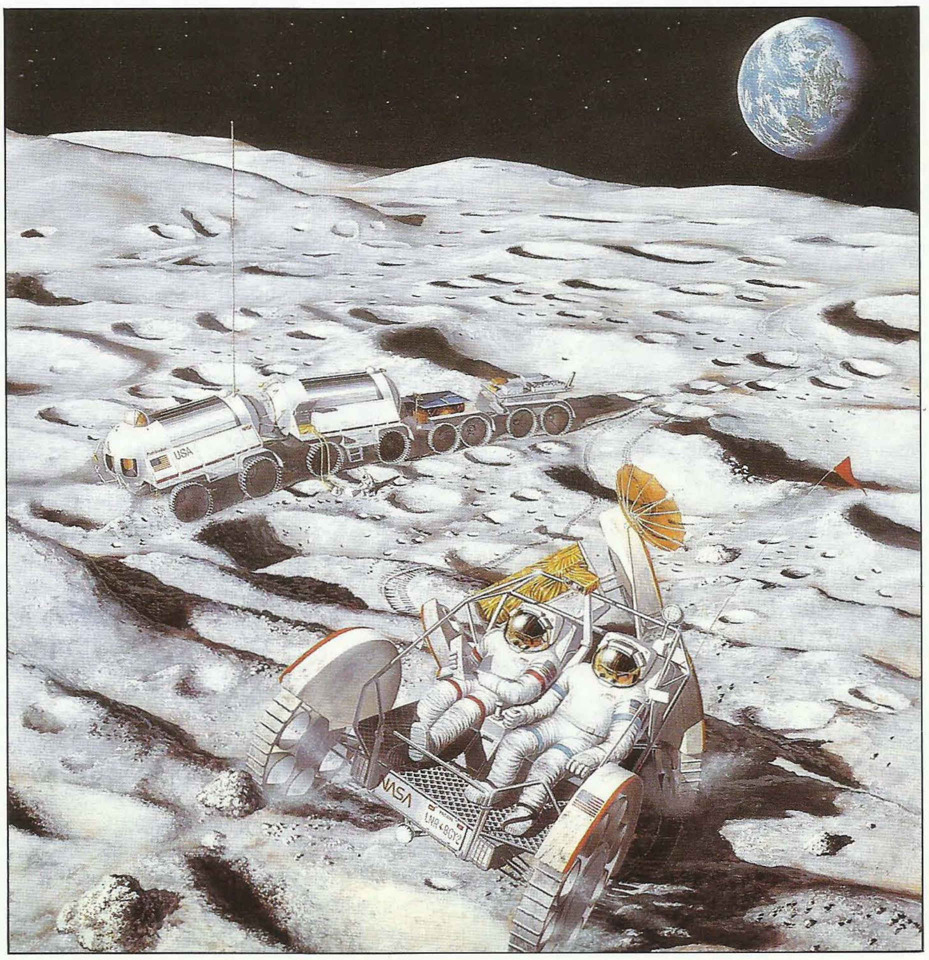
This lunar landscape depicts the arrival of a modular chamber from Earth that could be used to form living and work quarters for personnel. The unit will be moved to the site in the background and buried for protection from meteoroid impacts. *NASA artwork by Pat Rawlings*

eas, such as the region around Aristarchus, for possible vents and associated mineralization, lava tubes which could make natural base shelters and other physical and compositional features (Fig. 5).

Material Resources

First consideration of material resources is given to a site's ability to

MOSAP and LOTRAN vehicles on a scouting mission. *JSC/NASA*



payload or two additional crewmembers, depending on the task requirements. The second joint can be disconnected for trips not requiring the trailer section.

The pressurised vehicle system, MOSAP (mobile surface application traverse vehicle), has a maximum range of 3000 km with a nominal speed of 10 km/h. It also has a passive suspension in the form of cone wheels. The complete system is a four-piece modular design to allow flexibility in mission planning. Each of the four units can be individually operated or connected in the train configuration shown below and controlled by the first unit, the primary control research vehicle (PCRV). The units following the PCRV are the habitation trailer unit, the auxiliary power cart, and the experiment and sample trailer. Most tasks, such as crew transfer and medium distance survey or sample collection, will require only the PCRV.

Extremely long traverses will be accomplished by using a landing craft with crew module flying round trip from lunar orbit. Basing the landing craft at the outpost and "hopping" from site to site would not be as energy efficient.

Reference

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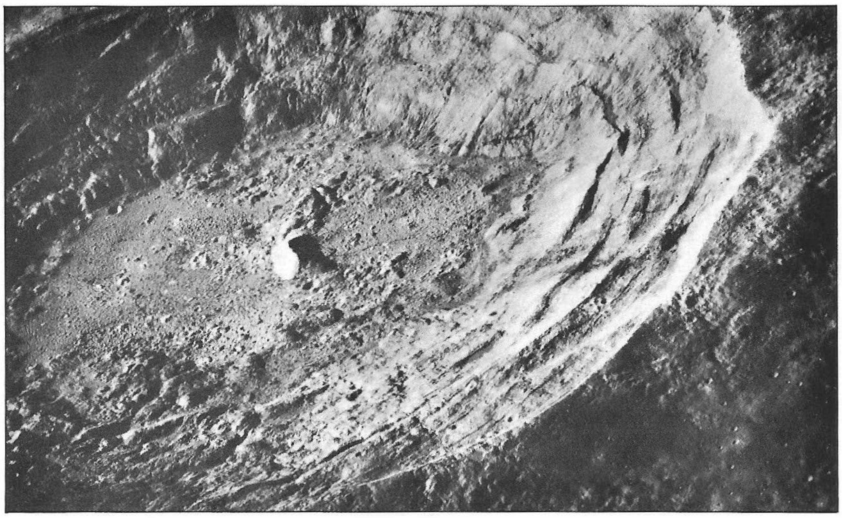

Fig. 5 The area around the young crater Aristarchus is of volcanic origin.

support local operations. At least meter-deep (and preferably deeper) regolith (loose soil) is desirable for burying initial habitation structures to suitable depth for long term cosmic ray and solar flare shielding. Two meters of loose material protecting inhabited structures from all directions, achieved by a combination of trenching and burying, is considered adequate. Mechanical properties should offer easy excavation. Ilmenite-rich mare (lunar "sea", or lowland) soil provides slightly superior radiation protection for a given thickness than lower density highland material, but this is not likely to be decisive advantage in base construction.

Second consideration is given to reducing the need for costly importation of terrestrial material for functions easily replaced by lunar material. Perhaps the simplest processed lunar material is cast basalt (a family of igneous rocks common to the Earth and Moon, formed when certain types of lava cool on the surface. An example of basalts are the majority of the Hawaiian Islands and lunar maria). Results from Earth-based testing indicate that basalts appear to be of suitable composition to be melted, poured into forms, and cooled into bricks and more complex structural forms. It can also be spun into insulating rock wool, as has been done in some terrestrial industries for decades. Melting and sintering (heating and forming without melting) temperatures are about 200 degrees celsius less for lowland mare basalts than for typical highland materials, and therefore require less process heat. Materials for production of some metals, solar cells, cement (based on CaO, calcium oxide), concrete, etc. may be more easily extracted from highlands although concentrates from mare materials will be adequate. Some highland materials produce a higher-strength, more transparent glass. For simple building materials, a mare site is superior but highland materials will work.

Volatiles in lunar samples have been shown to originate from solar wind implantation. Concentrations of hydrogen, carbon and nitrogen, the most valuable for life support and propellant, are available from lunar soils and regolith breccias (a rock composed of chunks of smaller, older rocks which have been fused together in a geologic process). Because these elements implant over time on the surface of mineral grains, their mass concentrations are highest on smaller grains in older soils. Concentrations are much lower in solid igneous (volcanic) rocks. Retention on ilmenite grains is preferential to other common minerals. It is not clear that the bulk availability of solar wind-implanted hydrogen, carbon or nitrogen is sufficient for practical production quantities of propellant. Other possible sources of volatile compounds include cometary impacts. Water, carbon dioxide, methane, hydrogen sulfide, ammonia or other volatiles are unlikely to last long near the impact points, but could collect in polar cold traps.

Simple heating of lunar soils to 700 degrees C will liberate most of the volatiles, with heating above 1050 degrees C required to obtain most of the rest. Solar-driven processes could yield sufficient gases to make up for habitat leakage and other losses. Young crater rims and ejecta blankets are probably deficient in implanted volatiles; other areas with sufficient regolith depth (probably most of the Moon) are likely to be satisfactory, though there may be a preference for ilmenite-enriched regions.

Specialized ore bodies could take several forms. First, "ore" should be defined as a natural concentration of a useful substance to a level and in a form which makes its extraction economical. Most mineral concentrations remain to be discovered. Even on Earth, ore bodies are seldom discovered and never confirmed without on-site sampling. At this point we can only suggest a few kinds of lunar materials which might prove important to base location. A preliminary list could read, in descending order of importance: mare basalt regolith, ilmenite, iron, pyroclastic glasses with semi-volatiles, high aluminum content highland material, and KREEP (Potassium Rare-Earth Elements, Phosphorus).

Ilmenite has been discussed as a feedstock for oxygen production by chemical reduction, for its higher solar wind volatiles content, and for the potential to beneficiate (a preparation for processing where the useful content of the ilmenite is enriched) it from soil using relatively simple electrostatic techniques. However, no one has yet demonstrated that naturally occurring lunar ilmenite can be adequately separated from accompanying substances to form a suitable cost-effective feedstock. Therefore, ilmenite availability as a major siting criterion could be a trap. Early use of ilmenite is less often described in terms of a source of iron or titanium. Ilmenite is especially abundant (up to 20% by volume) in some Apollo 11 and Apollo 17 mare basalts. Ilmenite is most often associated with high- titanium basalts in maria. Metallic iron and nickel-iron grains make up a small fraction of soil, apparently the product of meteoroid impacts, lava crystallization and a chemically reducing environment. While not considered an important early base siting criterion, availability of reduced metals such as iron could become important later. Older terrains, with deeper regolith, presumably have more metallics, i.e., iron and nickel, which may be easily beneficiated magnetically.

For oxygen extraction, magma electrolysis (passing an electric current through molten rock), high temperature pyrolysis (alteration through heat) and fluoride processing are somewhat site-independent, though process energies may vary. Ilmenite reduction and pyroclastic glass processing require site-variable feedstocks (pyroclastic glasses are typically tiny broken beads, formed in explosive meteoroid impacts or volcanic events. They form when bits of molten rock cool too rapidly to form crystalline grains).

A conclusion of the April, 1990 Johnson Space Center lunar base workshop participants bears repeating: "...We conclude that from the point of view of resource utilization, a viable strategy would be to select a high titanium mare site, perhaps on or near a pyroclastic area, and near a highland area so that calcium-rich feedstock would also be available...".

Reference

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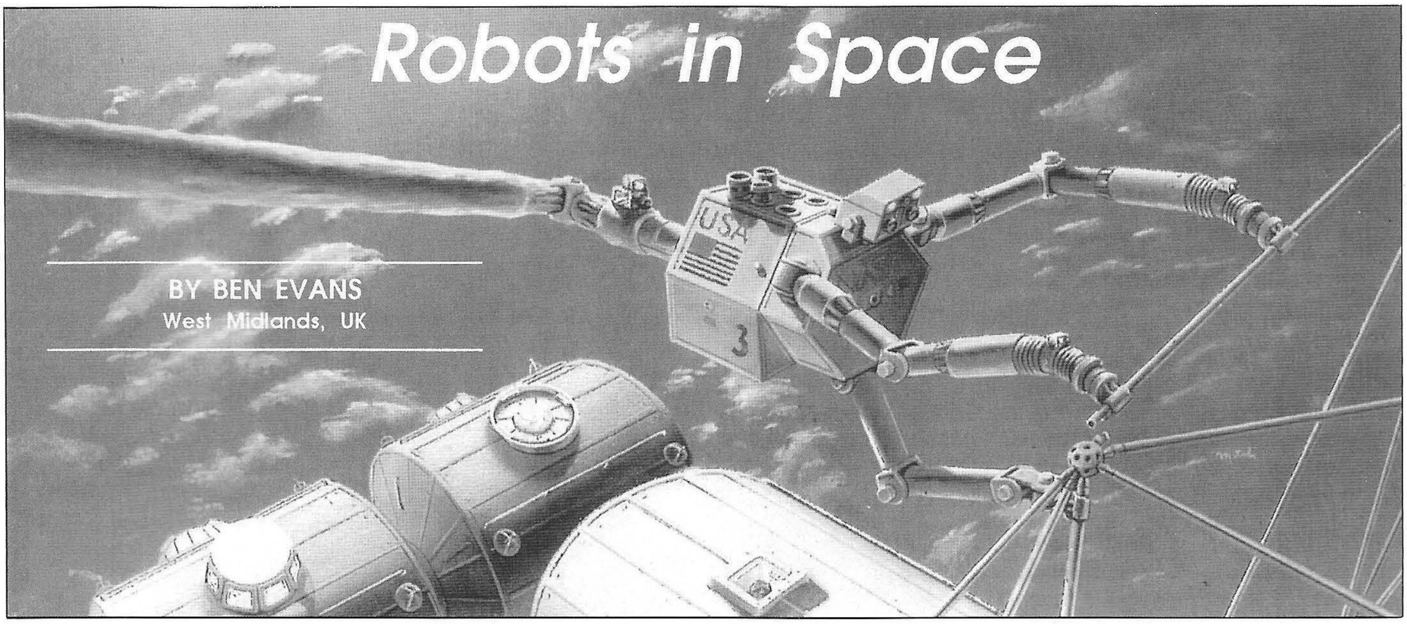


Robots in Space

BY BEN EVANS
West Midlands, UK

Artist's impression of the Flight Telerobotic Servicer installing truss members during Space Station Freedom assembly. *NASA*

The first real space robots were the spacecraft belonging to the unmanned Surveyor series which conducted numerous journeys to the Moon during the 1960s. Now, as then, plans for lunar and planetary exploration see robots as an essential tool.

The First Robots in Space

The main objective of the Surveyor programme was to soft land a series of unmanned spacecraft on the Moon's surface to firstly determine whether such a manoeuvre was feasible prior to the Apollo manned missions and secondly to help evaluate possible Apollo landing sites. Seven missions were flown, the first being launched on May 30, 1966 and the last on January 7, 1968. All seven were equipped with a spindly manipulator arm which closely resembled a pantograph in appearance. This manipulator was capable of digging a trench up to 1 m away from the spacecraft, and demonstrated the abilities of robots in space when used on Surveyor 7 to nudge open a soil analysis instrument which had earlier failed to automatically deploy onto the surface.

By contrast, the arms used on Soviet Moon landing spacecraft were little more than booms onto which were attached surface drills and coring devices. These were deployed onto the surface via simple electronic and radio commands transmitted from Earth stations, before returning a small sample of lunar soil to the return capsule.

The First Use of 'Telescience'

Telescience is the field of robotics whereby landers, manipulator arms or orbiting spacecraft can be controlled 'live' by an operator either in a spacecraft or down on Earth. The first demonstration of telescience came in November 1970, when a small roving vehicle affectionately nicknamed the 'mushroom on wheels' trundled down the ramp from the Soviet Luna 17 landing vehicle onto the Moon's surface at the Sea of Rains.

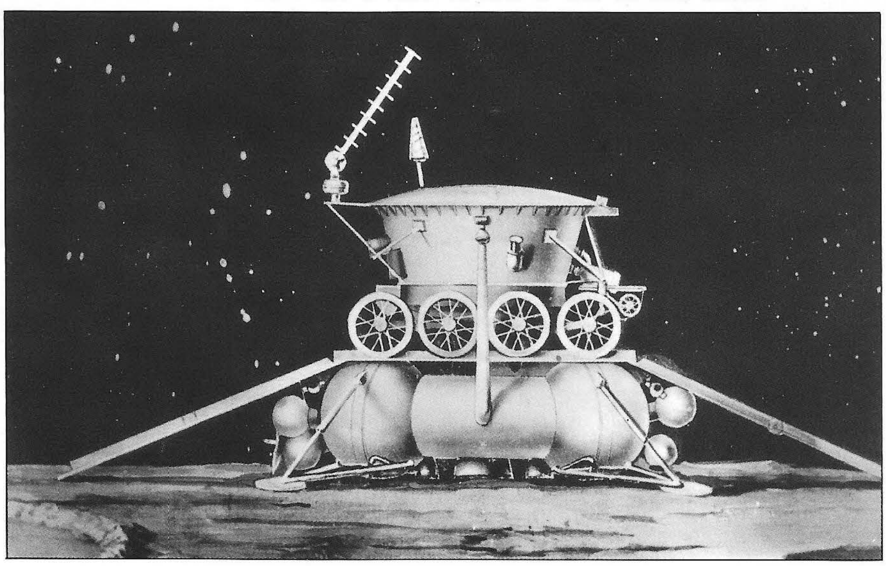
For the following eleven months the rover, known as Lunokhod 1, was manoeuvred over the treacherous lunar terrain under the direction of a four-member control team located in an Earth-based ground station. The rover was equipped with four television cameras to provide a full 360 degrees of vision, and also carried sensors capable of automatically stopping Lunokhod's movement if an incline was too steep or the vehicle's angle of tilt was too great. Lunokhod 2, which followed in January 1973, was a great improvement over its predecessor in terms of a higher speed capability and more complex scientific instruments. As a result, it required a five-person team to control its traverses across the lunar surface. Due to its advanced capabilities, Lunokhod 2 covered four times as much terrain as its predecessor in just five months.

The two Lunokhods successfully returned a total of over 100,000 television photographs including 292 panoramic views, as well as over 1,000 soil tests [1].

The Viking Landers: A Triumph for Robotics

The two Viking landers, launched on August 20 and September 9 1975 respectively, surpassed the achievements of the two Lunokhod rovers and have been termed the first 'advanced' space robots. The objective of the Viking programme was to insert two spacecraft into orbit around Mars, and then release from each a landing vehicle which would attempt a soft landing on the surface. It was a tremendous requirement when one considers the still-primitive robotics and computer technology of the 1970s, and with this in mind NASA managers decided to employ two identical orbit-

Artist's impression of Lunokhod 1 prior to rolling off Luna 17 onto the lunar surface.

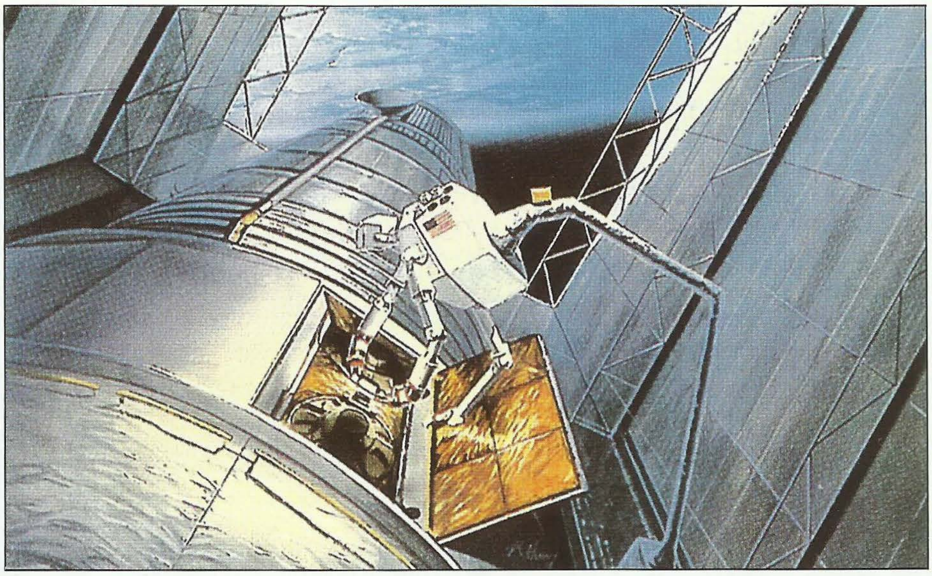


ers/landers to safeguard against failures en-route. Nevertheless, both spacecraft were very successful and while the landers conducted their research down on the surface in the full glare of public and scientific attention the two largely-unsung orbiters quietly mapped more than ninety-seven percent of the planet's surface.

With regard to robotics, however, the most obvious feature of the landers was a remote-manipulator arm capable of reaching up to 2.5 m from the main body of the spacecraft. The first use of the arm came on July 25 1976, five days after Viking 1's landing, and a soil sample was returned to the spacecraft and dropped through an opening into a miniature analysis laboratory. The shovel at the end of the remote-manipulator was fitted with special vibrators which shook fine particles of dust through a sieve to exclude large rocks which could clog the mini-labs. The Viking 2 lander touched down on September 3 1976 and its manipulator was extended nine days later.

The results obtained by both landers through their mini-labs have been intriguing to scientists. The experiments inside the mini-labs were designed primarily to stimulate and detect evidence of life, and Viking 1 discovered that an unusually high level of oxygen was produced when the soil samples were stimulated by sunlight or water! Could scientists have discovered evidence of photosynthesis on Mars? Ironically, the results obtained by the Viking 2 lander showed no signs of life, leaving open the question of whether life existed on Mars or not.

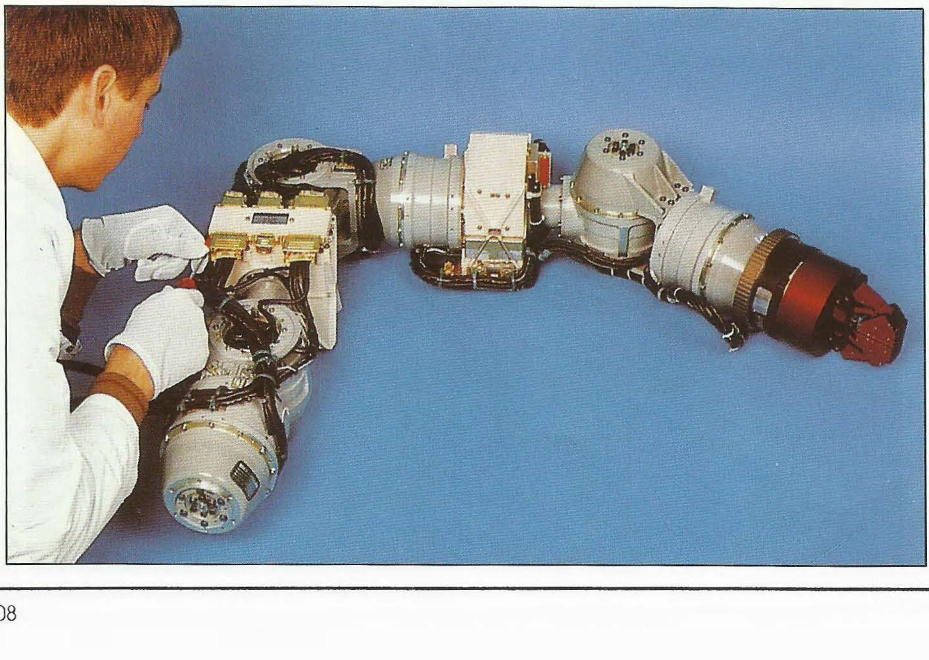
Overall, the Viking 1 and 2 orbiters continued to return data for four and two years respectively, while the landers operated for six and four years respectively [2].



Artist's impression of the FTS repairing the Hubble Space Telescope inside Freedom's Canadian satellite servicing centre. *NASA*

The Russian astromobile, model 96, equipped with French cameras, on trial in the Californian desert. *CNES*

Robots support work in space: the Rotex arm for the D2 mission (STS-55). *Deutsche Aerospace*



Telerobotics Applications on the Space Shuttle

Since the flight of mission STS-1/Columbia in April 1981, several robotic devices have been carried into orbit. The most famous and advanced to date is, of course, the Remote Manipulator System (RMS) mechanical arm, which has been used on several occasions to deploy, retrieve and repair satellites as well as to help assemble structures in readiness for space station construction.

The RMS arm was developed by the Canadian company Spar Aerospace and, as a result, it is often nicknamed the 'Canadarm'. It measures 15 m in length and closely resembles a human arm in that it contains a shoulder, elbow and wrist joint. The RMS arm was developed back in the 1970s with the intention that it should be capable of lifting a full Shuttle payload of dimensions 20 m long by 5 m wide and maximum weight of 29,483 kg. However, in 1991 NASA awarded a study contract to Spar to modify the arm such that it will be capable of lifting the weight of the entire Space Shuttle (108,862 kg)! When this new RMS arm is completed and flight tested, it will prove exceptionally useful during space station construction later in the 1990s.

The RMS underwent its first orbital flight test during the second Shuttle mission, STS-2/Columbia in November 1981. Over the following two years its muscles were repeatedly tested using oversized dumb-bells and giant 'cotton-reels' prior to the flight in April 1984 which really made its name - the repair of the malfunctioning Solar Max satellite. The arm was used to grapple the satellite, lower it onto a special mounting plate in the Shuttle's payload bay where it was repaired by spacewalking astronauts, and finally

redeploy it into orbit. A similar retrieval was accomplished in November 1984 when the arm captured two errant communications satellites and returned them to Earth for refurbishment and resale. In January 1990 and June 1993 respectively, the arm was used to recover from orbit the Long Duration Exposure Facility (LDEF) and European Retrievable Carrier (Eureca) free-flying satellites, although its most spectacular achievement of recent years came in May 1992 when it successfully captured the commercial Intelsat VI communications satellite and, after repairs and the attachment of a new boost motor, redeployed it into orbit.

Telescience received yet another boost in April 1993 when the first Robotics Technology Experiment (ROTEX) was carried into orbit in the German-sponsored Spacelab-D2 science laboratory aboard the Space Shuttle Columbia. The German-developed ROTEX consisted of a six-jointed remote-manipulator arm and sealed working cell located inside an experiment rack aboard the pressurised Spacelab module. However, whereas the RMS is manipulated from within the Shuttle's crew cabin by an astronaut using a joystick, the ROTEX is controlled live by an operator at the ground station in Germany.

Although little more than an experiment at present, ROTEX has been described as the most advanced robotic device ever carried into orbit, and its abilities reflect this. ROTEX is fitted with two torque sensors at its base which ensure that the arm does not become overloaded or overbalanced, while laser distance-measurement sensors, tactile sensors and stereo television cameras give a 'robot's eye' view of the target and adorn the gripper mechanism. In addition to the cameras on the arm itself, two other fixed video cameras provided stereo pictures of the entire ROTEX assembly in operation for the benefit of both the astronauts and the ground-based operator [3].

For its maiden flight, ROTEX was required to accomplish several simple tasks such as building a small tower of cubes and capturing an object floating free in microgravity. Both activities were successful, demonstrating yet again the abilities and potential of robots in space. Further, more complicated, flights of ROTEX are expected over the next few years, possibly on the European Spacelab-E1 mission in 1997.

The Flight Telerobotic Servicer

In mid-1992 NASA was forced to cancel several of its science programmes as it struggled to adhere to its budgetary commitments. One of the programmes cancelled was the Flight Telerobotic Servicer (FTS), which had been scheduled to make its first demonstration test-flight aboard a Shuttle mission in early-1994.

Development of the FTS began in earnest in December 1987 when NASA's Goddard Space Flight Center of Greenbelt, Maryland awarded parallel-study contracts to two aerospace companies for preliminary design and definition of a 'space robot' whose initial tasks would be to assist astronauts in the construction and maintenance of the Space Station Freedom.

NASA hoped that the robot would enable astronauts to direct routine assembly and maintenance operations without leaving the repessurised confines of the Shuttle or Space Station. As a result, the FTS would enhance crew productivity and safety by reducing the risk of high numbers of risky spacewalks. The FTS would have consisted of a hexagonal 'bus' section onto which would be mounted three highly-dextrous remote-manipulator arms and two stereo video camera 'eyes' for viewing, and would also boast advanced control systems. Eventually, it was envisaged that the robot could be used as a testbed for AI (Artificial Intelligence) programming which would allow the robot to 'think' for itself like a human to perform tasks.

Pending a successful 1994 demonstration test-flight, the FTS would have been declared operational and launched during an early Space Station-assembly Shuttle mission in the mid-1990s. For actual Space Station assembly operations the FTS would be attached to either the Space Station or Space Shuttle RMS arms, while the crew members onboard the Station or the Shuttle would direct the proceedings [4].

In spite of the cancellation of FTS, bold plans for robots in space do still exist, with roving vehicles and automated ground stations scheduled to be deposited on the surface of Mars during the international Russian/European Mars-94 and Mars-96 missions scheduled for launch in 1994 and 1996 respectively. Indeed, an improved version of the original FTS is likely to come back on the scene when Space Station assembly goes ahead. When advanced manipulator arms based on the Shuttle RMS and German ROTEX devices become available they will inevitably find applications not only in Earth orbit but also on the Moon and Mars with the establishment of manned bases.

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History of Robots

The word 'robot' is derived from the Czech 'robota' which means 'serf' or 'forced labour', and was first used in this context as part of the title for Karel Capek's 1921 film 'Rossum's Universal Robots'. In the film, an industrialist named Rossum produced android labourers in his factory, although eventually the robots developed an intelligence far superior to humans and took over their masters. Similar films followed during the 1920s and 30s [1].

However, the idea of robots started centuries before the appearance of Capek's film. The earliest reference to them was made by the Greek poet Homer in his masterpiece 'The Iliad' of the eighth century BC, when he mentioned 'handmaids of gold, resembling living young damsels'. The first practical 'robot' was an early mechanical 'doll' invented by Archtas of Tarentum (a friend of the Greek philosopher Plato) around 350 BC, and it involved a wooden pigeon suspended on the end of a bar which was caused to revolve thanks to continuous jets of compressed air.

The development of these 'mechanical dolls' continued over the centuries, culminating in a form of 'talking head' and an 'iron man' invented by respectively Roger Bacon and Albertus Magnus during the thirteenth century AD. In addition, the German astronomer Johann Muller created a mechanical eagle which was supposedly capable of actual flight! Such mechanical devices were popular in England during the eighteenth century as a form of entertainment, and they were made extensively by inventors and showmen.

The technology to actually build real robots for work did not make itself apparent until after the Second World War. Less than forty years ago, the first US patent for a robot was issued to a man named George C. Devol. He and his business partner Joseph F. Engelberger were both avid science-fiction enthusiasts, and through their work they successfully developed the world's first 'manipulator', a device capable of moving objects around in much the same manner as an arm or crane, in 1958 [2].

The early research of Devol and Engelberger has given way to tremendous advancements in both robotics technology and computer science, and today robots are indispensable to industry, to medicine, and to the space programme. Although the robots of today may not resemble the popular 'humanoid' concoctions such as C3PO and R2D2 from movies such as 'Star Wars: Return of the Jedi', they are perfectly capable of many tasks envisaged by science-fiction writers.

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25 Years Ago . . . The Cosmonauts Missed

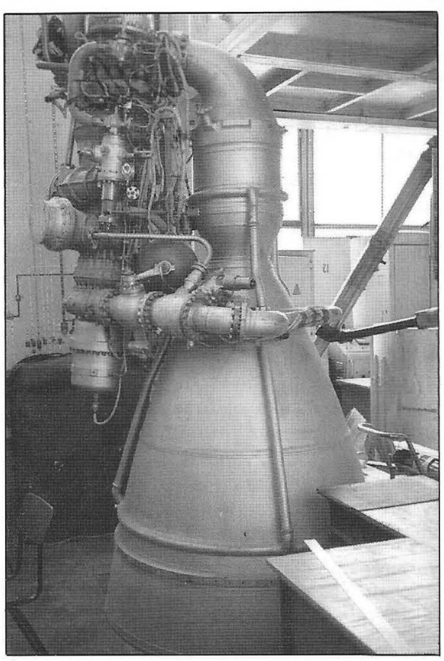
BY THEO PIRARD, FBIS
Belgium

1968 was the crucial year in the now admitted race to the Moon between the USA and the USSR. The high secrecy of Moscow added suspense to the historical events. During the 1970s and 1980s, official statements from the Soviet Union repeated that there was no race because there had been no participation nor interest from Moscow. The USSR explained and demonstrated that automated spacecraft were able to pick up Moon samples and to return them to Earth. However, the reality was completely different.

Many recent revelations made by high-ranking engineers during visits to museums, institutes (Moscow Aviation Institute) and industrial facilities (NPO Energiya) allow us to assess more accurately the events which finally excluded the Soviet space power from the manned race to the Moon. It is now clear that there was strong competition inside USSR, especially in Russia, between high-level engineers leading research teams and test laboratories. This internal competition and the low budget for manned exploration of the Moon explain the failure of Soviet technology against the successful Apollo programme.

At the beginning of 1968, the USA was really in trouble with preparations for its "Man on the Moon" programme. The reliability of the Apollo spacecraft was in serious doubt after the dramatic fire which, in January 1967, killed the first crew NASA named to test in orbit the 3-people cabin. However, on the other hand, the giant Saturn V launch vehicle was ready at the right time. The first launch of the powerful 111-m high rocket, developed by Wernher von Braun and his team, was used to test the Apollo 4 prototype for a simulated reentry from the Moon. The flight which was successfully completed on November 9, 1967 restored the confidence of NASA. Less than six months later, on April 4, 1968, the second Saturn V was launched for the Apollo 6 mission. In spite of only partially successful reentry tests of the Apollo 6 cabin, George M. Low, Apollo Spacecraft Programme Office at NASA recommended in early August to launch the third Saturn V with manned Apollo command and service modules for a flight around the Moon. These modules arrived at Cape Canaveral in mid-August. Internal work started quietly, without any publicity, for a mission in lunar orbit which was planned for December, during the Christmas week. However, NASA Administrator Thomas O. Paine was still concerned about manning the Saturn V, because of a risky pogo problem. Final approval to go to the Moon with a crew was given on November 11 after a decisive meeting with Apollo executives. On December 21, the Saturn 503 rocket lifted-off with a crew consisting of Frank Borman, James A. Lovell and William A. Anders. They became the first men to leave the Earth surroundings, to fly at the speed of 10.8 km/s, to see the fill disk of our planet and to fly around the Moon.

The NK-33 engine was developed for the first stage of the powerful N-1 launch vehicle: a total of 30 NK-33 engines achieved a thrust of 4,620 tons! *(Photo TP/SIC)*



During 1968, Soviet space institutes and industries were secretly but intensively busy on these four ambitions programmes in which they:

- tested integration and preparation of the impressive N-1 (Nossitel) rocket, 105 m in height, able to put 95 tons in low Earth orbit;
- worked on the modifications of the Soyuz vehicle which led to the death of cosmonaut Vladimir Komarov in April 1967;
- started work on the design of the manned system for a lunar landing in late 1969 or early 1970;
- concentrated their efforts on the Zond programme for a two-manned space flight close to the Moon.

On November 21, 1967, an unmanned Zond spacecraft failed to reach Earth orbit because of a malfunctioning second stage of the Proton rocket; the emergency rescue system returned the reentry vehicle to the ground. In early 1968, a mock-up of the N-1 vehicle was erected on its launch platform at Baikonur cosmodrome. Zond 4 was successfully launched on March 2, 1968, was able to perform a flyby of the Moon but one malfunctioning sensor for control attitude prevented its correct reentry. There was another launch failure of Zond on April 23, 1968 (just one year after Soyuz 1 dramatic test). Plans to accelerate preparation of Zond spacecraft became evident during the summer of 1968 when NASA had a plan to send astronauts on a mission in lunar orbit. Zond probes were being developed by OKB Korolev at Kaliningrad with Yuri P. Semyonov as chief constructor. Nowadays, Semyonov is the Director General of NPO Energiya, which builds the Mir modules and the Soyuz and Progress spacecraft.

Zond Test Programme

The next Zond was planned for launch on July 21, 1968, but there was the problem of a crack in the upper Block D stage of the Proton rocket due to over pressurization during fuelling which delayed it for two months. Launched on September 15, 1968, Zond 5 completed a successful flight, achieving the first recovery of a spacecraft with a biological payload, including turtles, from the vicinity of the Moon. After a ballistic reentry, it splashed down in the Indian Ocean, where a Soviet search-and-rescue ship pulled it out of the water. Zond 6, launched on November 10, used the double reentry technique to make a controlled descent reducing overloads to 4-7 g. Because of an early release of the parachute, its trajectory ended in a crashed landing on the territory of the Soviet Union. With this hard return the Zond spacecraft was declared unreliable for manned lunar operations. Nevertheless, the official statement about a Zond 6 success for propaganda purposes added some suspense to the Moon race; the Zond programme was described as aiming "to perfect the flight and construction of an automated version of the manned spacecraft for flight to the Moon."

The purpose of the Zond programme became clear at the end of 1968. Western observers expected that the pressurized cabin of Zond 7 could be sent to the Moon with two cosmonauts onboard for a historical "first" spaceflight. In fact, two teams of two cosmonauts were being trained at Star City for this audacious and risky mission: Valery Bykovsky and Nikolai Rukavishnikov, Pavel Popovich and Vitali Sevastianov. The launch had to take place on December 17, but did not occur. Aboard the Apollo 8 cabin, launched on December 21, three American astronauts became the first

the Moon!

people to achieve a historical trip and to celebrate Christmas Eve around the Moon.

While the Zond programme was progressing through technical difficulties, Moscow, nevertheless, took the decision to proceed with development of a manned system for Moon exploration. In 1969, it was planned to test the various elements with the aim of realizing a first Moon landing in 1970-71. In March 1968, the programme of cosmonaut training in preparation for this landing was started at Star City. A moon-walk simulator was installed in the gymnasium. A programme of simulated lunar landings took place with a modified version of the Mi-8 helicopter. Cosmonauts Alexeï Leonov and Oleg Makarov were selected to form the prime crew for the first Russian expedition on the surface of the Moon. This event was planned to take place in late 1969 or early 1970! Soviet industry was faced with some serious technical challenges in the development of the giant N-1 rocket: four vehicles (3L on February 21, 1969; 5L on July 3, 1969; 6L on June 27, 1971, and 7L on November 23, 1972) were launched from a new launch complex at Baikonur and were destroyed because of malfunctions with the complicated assembly of the 30 new NK-33 rocket engines (24 peripherical and 6 central, using oxygen and kerosene).

Four-Part Lunar Transportation System

In a monograph published in December 1991, which described the History of Soviet spacecraft for manned missions, engineer I.B. Afanasyev, revealed some interesting data about concepts and tests of the manned systems studied by the USSR for exploration of the Moon. He described the L3 complex, i.e. the lunar transportation system, which would be launched beneath the impressive nose fairing of the N1 rocket. This nose was topped by an emergency rescue system powered by a solid-propellant rocket which would be able to carry the upper part of the spacecraft with its living-working quarters and conical reentry cabin clear of the launch vehicle. This L3 Complex, which was meant to go to the Moon, had four elements formed by the linkup of two rocket units and two man-rated spacecraft. Both spacecraft with pressurized cabins were too very different vehicles, one to orbit the Moon and the other to land on its surface. They were developed on the basis of the Soyuz spaceship by OKB Korolev (now NPO Energiya) with the participation of Ukrainian OKB Yangel (NPO Yushnoye) for the propulsion system.

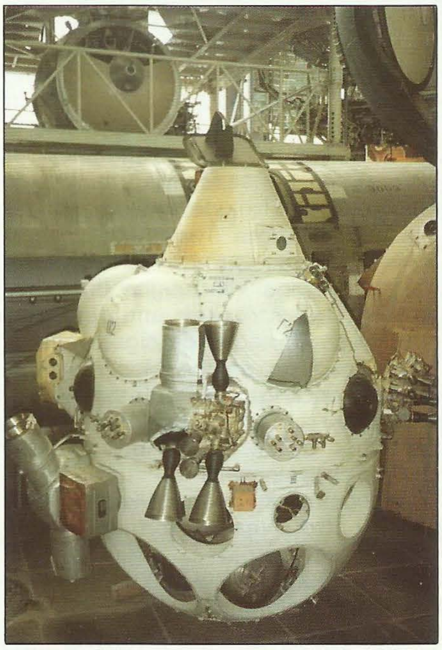
The LOK or lunar orbiter presents some identical features with the actual Soyuz spacecraft. There was no transfer tunnel ahead of the living/working module, but an exit door for EVA transfer was to be used. *(Photo TP/SIC)*

About the Author

Theo Pirard is a Fellow of the BIS of long standing and has contributed many articles and reports to ***Spaceflight*** on space developments from around the world. He is professionally engaged in supporting the media and publishers with space news and information and is editor-in-chief at the Space Information Center, Pepinster, Belgium.

The accompanying photo was taken during his visit to the Moscow Aviation Institute about which he writes in this article. He is seen holding a test model discovered in the waste disposal area of one of the test laboratories. *(Photo TP/SIC)*

- The lunar orbiter spacecraft or LOK (Lunova Orbitalny Korably) was the top half of the linkup. As with the Zond spacecraft, a 2-cosmonaut crew would spend most of the flight in the living quarters of LOK. The LOK looked like a great headlight: it consisted of spherical living/working quarters with a larger exit hatch, of a return vehicle having a conical shape and reinforced thermal protection (for atmospheric reentry at 11 km/s), and of an instrument-equipment bay or service module with an expanding conical "skirt". The front part of the spherical section would be equipped with a unique manoeuvring and docking unit: this active assembly had a honeycomb structure with simple-spring shock absorbers, with rendezvous and attitude control engines. The rear part of LOK would contain an instrument-equipment bay with a spherical fuel unit for the main propulsion system, which used the self-igniting propellants nitrogen tetroxide and unsymmetrical dimethylhydrazine. This propulsion unit, named Block I, was formed from a main 3.3-t thrust engine with two lateral chambers and a manoeuvring 417-kg thrust engine with one central chamber. The conical "skirt" was joined to a cylindrical shell inside which the lunar lander or LK was installed.



This propulsion unit with navigation systems of the LOK spacecraft was installed in the front part of the LOK for orbit manoeuvre and attitude control operations around the Moon. At the rear side, the upper part of the LK module is visible. *(Photo TP/SIC)*

- The LK (Lunova Korably) spacecraft differed from the Soyuz in its more complex electronics with systems for control, docking, communications and telemetry. Its more powerful power supply sources were based on fuel cells, named Volna. This fuel cell of 70 kg was able to generate 1.5 kW at 27 V for 500 hours. The LK consisted of a spherical, pressurized cabin in which only one cosmonaut, secured with special attachments, stood before an instrument panel and a landing viewport. There was no seat in order to save mass; this design also was adopted by NASA inside its lunar module. On the upper part of the cabin were the docking passive assembly and the attitude-control vernier liquid-propelled engine unit; this assembly consists of a flat hexagon made in honeycomb material.

Soviet designers did not go for the more comfortable tunnel for internal transfer from LOK to LK habitats. They moved away from the complicated need to connect the electrical and pneumatic mains of two different spacecraft with the aim of forming a common pressurized system. They saved several hundred kilograms of mass and a great amount of time in the design and development of many "tight spots". For the docking operations, the active LOK spacecraft had just to move towards the LK module in order to fix a honeycomb structure with miniaturized cones anywhere in the plane of its passive assembly. The cones would attach together the honeycomb structures and both spacecraft would be pulled together by "claws", thereby providing the mechanical connection for the transfer of the "moon walker" between the two cabins, from the LK to the LOK.

On the lower part of the cabin, was the lunar landing equipment with the 2,050-kg thrust liquid engine, which would be heavily throttled and had a broad range of thrust regulation. It also burned the self-igniting mixture of nitrogen tetroxide/unsymmetrical dimethylhydrazine. The back-up propulsion system was provided by a 2-chamber engine with roughly the same thrust. These rocket engines with variable thrust had to be highly reliable for soft landing on the Moon and for return to dock the LOK with the second cosmonaut in lunar orbit. They were developed by I.I. Ivanov, belonging to OKB Yangel, now NPO Yuzhnoye of Dniepropetrovsk, in the Ukraine. Attitude control was performed by 16 microrocket engines, eight with a thrust of 40 kg and 8 with a thrust of 10 kg. A double control circuit was installed; each circuit controlled separately eight engines. The propulsion system was the main and crucial assembly of LK; its mass accounted for half of the craft's mass and it was located in the centre.

In order to inject in a translunar trajectory and to achieve a lunar orbit, the lunar manned system was completed by the two upper stages with powerful rocket engines, which together formed the LRK (Lunova Raket Kompleks). Respectively named Block G and Block D units, these highly efficient liquid-fuel rocket engines would burn nontoxic oxygen-kerosene propellant for two crucial manoeuvres on the way from the Earth to the Moon, until the LK module reached an altitude of 2 km above the lunar surface:

- First task of LRK: the launch from near-Earth orbit into translunar trajectory would be achieved by the Block G stage with one NK-31 (Kuznetsov) engine which would fire for 8 minutes to speed the L3 Complex to the Moon at some 11.2 km/s and then would separate from it.
- Second task in lunar orbit: all manoeuvres for trajectory correction and for transfer to circumlunar orbit would be performed with the Block D stage with multiple firings of the 8.5-t thrust rocket engine. In a first phase, the lunar system would be put in orbit at an altitude of 119 km, then transferred to an altitude of 16 km. One of the two cosmonauts - who was designated to land and walk on the Moon - would have to perform a EVA in lunar orbit for his transfer from the LOK to the LK cabin. After check-out, the LOK and LK spacecraft, each inhabited by one cosmonaut, would be separated. The conical adapter would be jettisoned and the descent of LK to the Moon could start with the firing of Block D stage engine which would propel LK to an altitude of 2 km over the Moon. Its reliable performance was essential for a successful descent.

Quick Descent and Limited Resources for Landing

Once separated from the LOK, the LK spacecraft would start a risky descent towards the lunar surface by using the Block D propulsion unit as a brake. At an altitude of some 1.5-2 km, this unit would become empty and be jettisoned. The LK module would become a fully autonomous vehicle with its own propulsion system for hovering at an altitude of several dozen meters above the surface of the Moon. The cosmonaut would visually select a landing site and the LK would begin its descent just lasting a few seconds. The landing procedure would be achieved in quick time: from the separation of the Block D element to the landing, for only one minute would elapse!

Control of the LK systems in manual mode was from a control panel developed by the design bureau headed by S. Borodin. This panel was installed to the right of the viewport. Viewing would be done through a collimator with projection of the landing site from the control system. The control stick would be used by the cosmonaut to align on the chosen region and the spacecraft would go to the target. An upper viewport also was installed for observing the docking with LOK. A wide-angle viewfinder fixed on the outside would inform the cosmonaut about the position of LK in relation with LOK during rendezvous manoeuvres in lunar orbit.

Russian engineer I.B. Afanasyev admitted in his report about manned spacecraft projects of the USSR that the possibilities for manoeuvring the LK over the Moon were extremely limited. If a soft landing became impossible, the LK would use its own propulsion system to come back into circumlunar orbit and to dock again with the LOK piloted by the second cosmonaut for a safe return to the Earth. Design and development of the lunar landing gear, consisting of four support legs with honeycomb shock absorbers, were delicate tasks because of unknowns concerning the slope and the diameter in the lunar craters. Finally, designers worked on a landing system for craters of some 7 m in diameter and with a slope of less than 20°.

Risky "Hoolahoop" Walk on the Moon

To walk alone on a "new world" was considered a challenging risk. Until now, no astronaut nor cosmonaut had done an EVA solo; two together in the space environment can assist each other in case of a space suit malfunctioning or a sudden sick feeling. The main problem on the lunar surface came from the danger of falling over backwards. The solution from the designers would be to furnish the cosmonaut with a light-weight hoolahoop that he would don as he descended to the lunar surface. Just imagine the scene of a cosmonaut in spacesuit walking on the Moon with a hoolahoop! This hoop would be secured by a catch on the waist of the space suit and be located primarily on the back. In case of a fall backwards, the hoop would enable the cosmonaut to quickly roll over on his side or his hands and pick himself up normally. The use of the moon hoolahoop was tested in an aircraft simulating lunar gravity.

The LK was designed to be autonomous for 72 hours. It could remain on the Moon for up to 48 hours, but for the first mission, this time would be shortened to only a few hours. After landing, the cosmonaut would check out the LK systems and would prepare the space suit for egress. Having verified the seal of the space suit, he would depressurize the cabin, open the portside hatch, exit to the platform on the landing gear and descend along a ladder. The performance of the semi-rigid Kretchet spacesuit would allow him to stay on the lunar surface for less than 90 minutes. A lot of activities on the Moon would have to be completed by the alone cosmonaut: to plant the state flag of the USSR, to deploy some scientific instruments, to collect lunar soil samples, to take the historical photographs and to conduct TV reports. After this brief lunar visit, the cosmonaut would abandon the hoop on the lunar surface, climb back to the cabin and bring inside a sealed container with the precious samples. The cabin would again be pressurized. The cosmonaut would take off the space suit and have a merited rest through sleeping in a standing position.

The departure from the Moon and the docking with LOK, which, in circumlunar orbit, would be the active spacecraft for rendezvous and docking manoeuvres, would represent the next crucial steps. Electrical, pneu-

matic and mechanical systems of LK, especially for the Ye (Yangel) rocket engine, would be severed. The engine which burns self-igniting propellant would fire. LK would lift-off, leaving the landing gear on the Moon, and follow a trajectory to fly in orbit around the Moon. The LOK spacecraft, using a powerful radar scanning system, would be piloted by its passenger with visual observations through the view-port. LOK manoeuvres would use the 417-kg thrust engine of the Block I unit. The success of the docking would be followed by the transfer through EVA in lunar orbit (again) from LK cabin to LOK living/working module. The moon walker would to carry with him the container with the soil-samples!

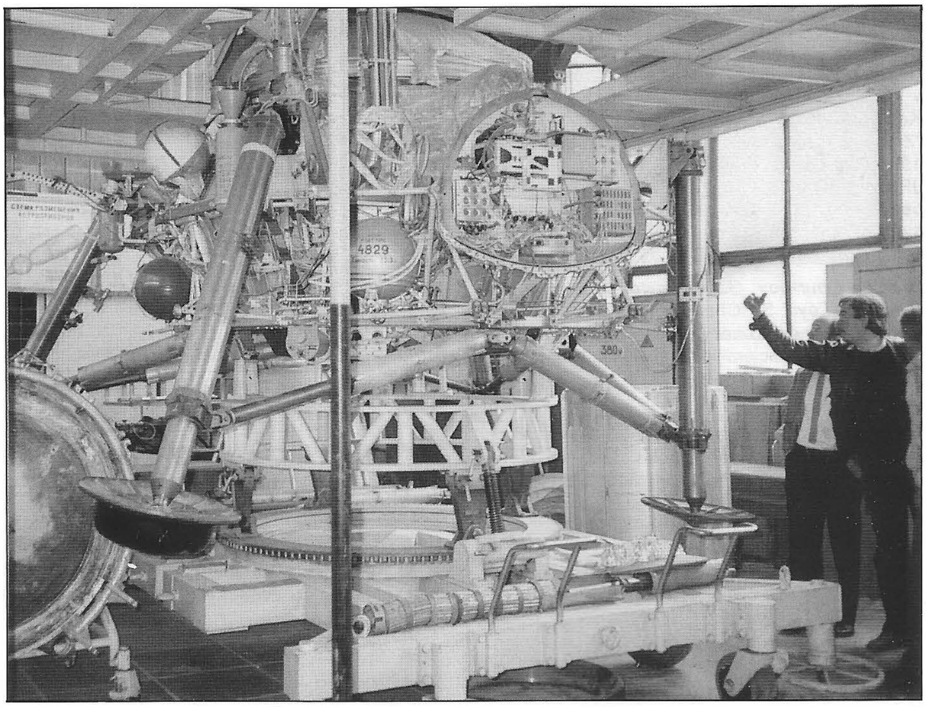
The return to the Earth would be made after the LK had been jettisoned. The LOK spacecraft again inhabited by two cosmonauts would enter a precise Earth-return trajectory by firing the powerful 3.3-t engine, consisting of two lateral chambers mounted on the sides of the manoeuvre engine. Before reentry in the atmosphere, the front compartment and module of LOK would separate and the conical capsule would enter the atmosphere at nearly 11 km/s. As tested with the Zond spacecraft, the LOK capsule would achieve a controlled reentry trajectory with safe low-g levels. Like the existing Soyuz cabin, it would land softly in the Southern part of USSR, braking by parachutes and solid retrofire motors. Because of the failures in the development of the N-1 launch vehicle, these events never happened!

Moon Lander Ready to Fly in 1971

The flight test programme of the lunar complex used two prototypes: the T1K and T2K were intended to test the rocket units in weightlessness with all systems in routine operations. T1K was for testing the LOK on the Proton booster; the second was used for testing the LK on the Soyuz booster. The Ministry of Industry put pressure on reducing the number of experimental craft. Only tests of the T2K spacecraft remained because of the efforts of Academician M. Yangel to get approval and funding for propulsion experiments. The T2K had nearly 20 systems and test flights around the Earth called for the launch of three units. Preparation of the T2K spacecraft was a real problem.

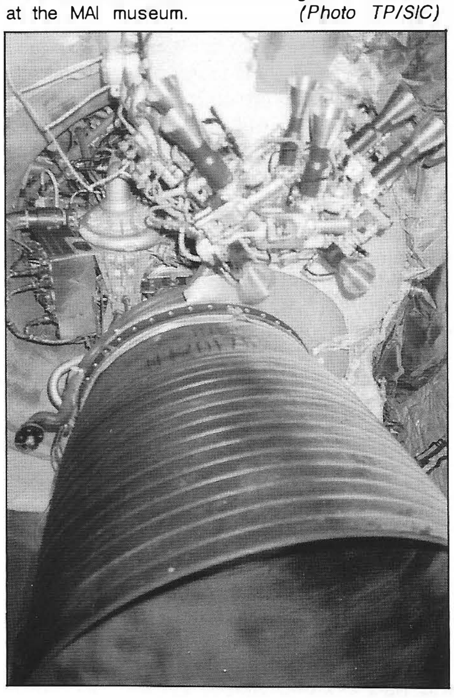
The first T2K was launched under the name of Cosmos 379. This launch took place on the sunny morning of November 24, 1970 and simulated the routine cycle of operations with the rocket engine of the lunar module. Of particular concern was the matter of testing the operation of the instruments to determine the position of the axes of the lunar module in flight. Ion sensors were installed on the T2K for sun/planet acquisition. After entry into 192-232 km orbit, the Ye engine was fired 3.5 days later and, under heavy throttling, increased the speed of the vehicle and simulated the hovering of LK over the lunar surface. The orbital apogee reached the altitude of 1,210 km. On day 4 of Cosmos 379, the engine was fired for the second time. The speed was increased by more than 1.5 km/s, to simulate the entry of the LK into lunar orbit for rendezvous with LOK. The result of that manoeuvre is that the orbital apogee rose to 14,035 km. Following the statement of Vyacheslav Filin, now Deputy Chief Designer at NPO Energiya, everything was going as planned: "there was not a single problem with the craft's system during the test, which meant that it had worked with good effect."

The second T2K was tested under the name of Cosmos 398. It was launched on February 26, 1971 and duplicated the first. Various contingency modes were simulated during this test. After two firings of the Ye engine, Cosmos 398 went into an orbit between 203 and 19,903 km. The third T2K or Cosmos 434 flight started on August 12, 1971. During this test, Cosmos 434 achieved the longest burn in throttle mode to put T2K up to an apogee of 11,804 km. The spacecraft was declared ready for manned missions, but that time never came. The giant moon rocket of the USSR could not be made reliable and the USA made successful landings on the Moon: 2 in 1969, 2 in 1971 and 2 in 1972. Automated spacecraft, named Luna 16, were able to bring back some specimen soil from the lunar surface. The work with the T2K spacecraft demonstrated that the Russian and Ukrainian industries have the technical capabilities to develop a long-duration vehicle for expeditions on the Moon and Mars. A model of the LK is stored in the Museum of the Moscow Aviation Institute (MAI): Professor Oleg M. Alifanov, Chairman of College of Cosmonautics at MAI, allowed us to take pictures of the historical piece. It is reported that the first LK mock-up is placed in A.F. Mozhaisky Institute at St Petersburg.



The landing gear of the LK module is clearly visible on this prototype stored in the Moscow Aviation Institute and used in connection with courses about space technology. *(Photo TP/SIC)*

The crucial propulsion unit for lunar manoeuvres: the Block D rocket engine is exhibited at the MAI museum. *(Photo TP/SIC)*



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Special thanks to Russian Prof. Oleg M. Alifanov, French specialists Christian Lardier and Stephane Chenard, to American specialists Charles P. Vick and David R. Woods.

***Bibliography** - see overleaf.*

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Mishin Vassily P., On Failure of Soviet Manned Lunar Program, in Novoye v Zhizni, Nauke, Teknike: Seriya Kosmonautika-Astronomya, Izdatelstvo Znaniye, Moscow, 1990, n°12, December 1990 (English translation made by JPRS [Document JPRS-USP-91-006] on 12 November 1991, containing a lot of first-hand revelations about the Russian efforts in the manned exploration of the Moon).

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At the entrance of the College of Cosmonautics, Moscow Aviation Institute, this mosaic shows the ambitions of the former USSR in the development of space technology. *(Photo TP/SIC)*

The Heritage of Russian Know-How in Space Technology

A high modern building surrounded by many aged laboratories, located in an active and pretty part of Moscow. It houses the main high-tech education facilities of the former USSR: the Moscow Aviation Institute or MAI. Established in 1930, it is the Russian equivalent of the California Institute of Technology or Caltech, but mainly specializes in aerospace engineering science and technology.

Some 18,000 people, most of them from Russia, are studying with 800 professors and engineers in nine different faculties or colleges, which cover all the aspects of aerospace activities:

- Aircraft & Helicopters Systems
- Power supply systems
- Onboard management systems
- Radio & electronics systems
- Economic organization of production
- Cosmonautics & applications
- Robotics & applications
- Mathematics & applications
- Mechanics & applications

The College of Cosmonautics, described by Chairman Prof. Oleg M. Alifanov, is organized in nine departments:

1. Space rocketry systems (Director: Prof. Alifanov). This department was established since 1958 by Sergey Korolev, with, as first Director, Vassily Mishin, who was responsible for the N-1 programme. Consisting of 30 professors and 80 engineers, it provides technological know-how in the design of spacecraft, in reliability of space systems, in the use of automated instrumentation, in the study of liquids under microgravity.
2. Building of Space Systems (Director: Prof. Golobiev). It is specialized in the studies of automated manufacturing processes for reliable space structures and materials.
3. Structures & Materials (Director: Academician Abrasov). It is concerned with studies in the design and testing of new materials for aerospace applications.
4. Flight management and Navigation systems (Director: Prof. Malyshev). It works on the optimization of trajectories, of spacecraft and of control systems.
5. Tests of Rocket systems and development of Rocketry infrastructure (Director: Prof. Afanassyev). Problems related to ground facilities to test and launch rockets for missions in space.
6. Processing technologies for space operations (Director: Prof. Bilinkov). Design and development of new processes for operations in the space vacuum.
7. Life support systems for space operations (Director: Prof. Ganzerinck). Concerned by medical and ergonomic problems of manned spaceflight, it studies meals, seats, space suits, emergency systems, personal communications and manoeuvring units for EVA. It works in connection with NPO Zvezda and Gury Severin.
8. Hydrodynamics & Applications (Director: Prof. Tarasov). It works on systems in the air and in water for simulating space conditions.
9. Informatics & Automatisation (Director: Prof. Smirnov). It designs and develops software for automated operations in cosmonautics.

The MAI has direct and close connections with Scientific-Production Associations (NPO), with Construction Bureaus (OKB), with Scientific-Technical Centers (NTT), with Scientific Research Institutes (NII). MAI students are regularly sent to these industrial, technical and scientific facilities. Since 1989, it is organizing an annual International Aerospace Summer School with students not only from the USA but also from other countries. A special entity is established for the organization of the annual sessions: the International Center for Advanced Studies "Cosmos" (Director: Prof. Oleg M. Alifanov).

The main purpose of "Cosmos" is the study of advanced topics of spacecraft design and construction. Participants attend courses with high-level specialists and with aerospace industrial visits in these disciplines:

- spacecraft systems engineering and design;
- trajectory optimization;
- guidance and control;
- aerodynamics, rarefied gas dynamics;
- heat and mass transfer;
- behaviour of fluids in zero-g;
- strength of high temperature structures;
- life support systems;
- testing of launch vehicles and their subsystems.

In addition, students of the International Center for Advanced Studies "Cosmos" take part in one of several projects related to the design and construction of unmanned and manned spacecraft for Moon base and Mars expeditions. These design projects are carried out together with engineers and students of the MAI Student Space Design Bureau.

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VOLUME 35, 1993

Editor: G.V. Groves, FBIS

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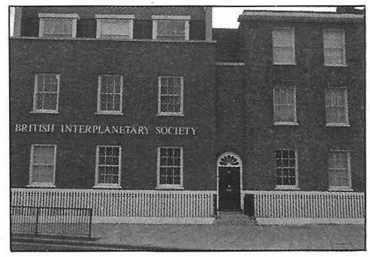
COMPUTER SOFTWARE

60 Years



The British Interplanetary Society is a pioneer body which takes a long-term view of space developments, which it regards as steps in man's history towards a greater and boundless environment. It is the oldest solely space-oriented body in the world.

History of The Society

The Society originated in Liverpool on 13th October 1933. It began as a small body of enthusiasts which, by 1936, had grown to such a degree that its operations were moved to London. In 1938-9 it undertook a design concept for a lunar landing vehicle which, in retrospect, incorporated many features utilised in the American Apollo Lunar landing missions of 1969 to 1972.

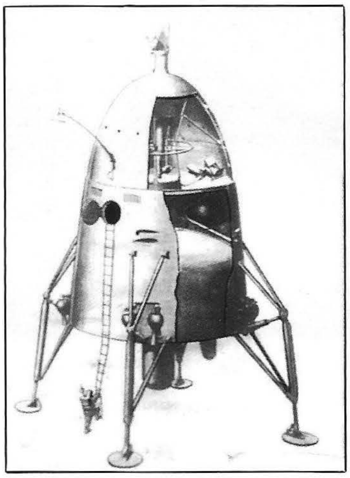
In 1945 The Society, re-established as a Company Limited by Guarantee, rapidly grew and originated and published a host of unique space concepts.

Space applications were studied over a wide range, including the concept of communication satellites first suggested by Arthur C. Clarke (then Secretary of the Society) which was evaluated in a private memorandum circulated among selected Fellows of the Society prior to publication in 1945. Other concepts included satellites for geographical, geodetic and navigation purposes and for remote sensing. Studies were undertaken for probes destined to explore other planets, the design and construction of space-stations and an examination of the possibilities for nuclear-propelled rockets for deep-space exploration.

Later Society activities have included Project Daedalus, a concept for interstellar exploration which paved the way for hundreds of technical articles on the problems involved in reaching the nearest stars and exploring the possibility of life existing elsewhere in the Universe.

The Society has consistently supported the creation of national and international bodies needed to develop a space infrastructure, including ELDO, ESRO, Eurospace, ESA, Inmarsat and the British National Space Centre.

From its establishment, the Society has always been international in its character. In accord with these aims, it was a founder member of the International Astronautical Federation in 1950 and has been the UK voting-member of that Organisation ever since. Its programme, both at home and abroad, and over many decades, has embraced a multitude of joint projects designed to promote and support international space activities.

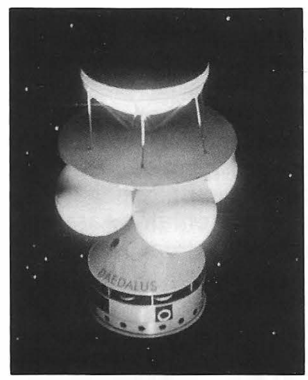


Artist's impression of Liquid Propellant BIS Lunar Rocket, 1946.

Presentation to Valentina Tereshkova, the first woman cosmonaut, on 5th February 1964.

Presentation to the Apollo 11 Astronauts. Left to right: Dr Tom Paine, (NASA Administrator). Apollo 11 astronauts: Neil Armstrong, Buzz Aldrin, Michael Collins.

British Aerospace stand at Space '87 Exhibition to coincide with the 38th IAF Congress hosted by the British Interplanetary Society at Brighton.



Model of the Daedalus design-study (1978) for an interstellar probe.

Space Achievement Medal Presentation to Helen Sharman at the Royal Commonwealth Society on August 7th 1991 before an audience of 400 members of the Society and their guests.

Messages to the Society

The Society enjoys close relations with many international organisations and other bodies who have written to the Society on the occasion of its anniversary. These messages, together with those from BIS members and others, were read out at the Society's Anniversary Banquet at SPACE '93 on 16 October.

Mr Martin Fry, Vice President, reads out messages of congratulations to the Society at the SPACE '93 Anniversary Banquet.

From: NASA

Please accept my warmest congratulations on the occasion of The British Interplanetary Society's Diamond Jubilee.

When others were just dreaming of space exploration, the Society was in the vanguard of creative thinking. Its innovative ideas for the exploration of the universe and the development of space technology have fostered enthusiasm for extraterrestrial research throughout the world. I am proud that the National Aeronautics and Space Administration has been able to be a part of the Society's exciting history of informative lectures, conferences, and symposia.

I wish you and the Society continued success in the coming years with your important mission.

Daniel S. Goldin
Administrator

From: EUTELSAT

It is a great pleasure for me to congratulate the British Interplanetary Society on the occasion of its sixtieth anniversary, on behalf of the members of the European Telecommunications Satellite Organisation, EUTELSAT.

Space communications, together with environmental awareness and humanitarian action, are among the factors contributing to the growth of a "global conscience".

Their true impact will only appear in the next century, but we are proud to be part of the pioneering space family, and wish the British Interplanetary Society much success in the coming decades.

Jean Grenier
Director General

From: INMARSAT

On behalf of Inmarsat, I would like to convey my warmest congratulations to the Society on its reaching such a productive middle age, and on its achievements during its first six decades.

It is a period which has spanned tentative experiments in rocketry through to the manned landings on the Moon and the exploration of the planets. From my perspective, it has also been the period when we have begun to use space for the benefit of mankind. It is hard to imagine now a world without satellite television and communications, satellite weather maps, surveying and exploraiton, and position determination.

The future will hold many more exciting projects and applications, many of which I am sure will benefit from the pioneering imagination and expertise of your Society's membership.

Olof Lundberg
Director General

From: INTELSAT

On this occasion marking the sixtieth year of operation of the British Interplanetary Society, INTELSAT is proud to acknowledge links between the Society and INTELSAT from the early origins of INTELSAT, almost half the lifetime of the BIS. INTELSAT Management and all of the member organisations of INTELSAT around the world congratulate the British Interplanetary Society both on its anniversary celebration and the important contributions that it has made over this period of space activities.

Please accept our best wishes that the next sixty years may be as fruitful.

Irving Goldstein
Director General

From: BNSC

The past 60 years have seen a blossoming both of Man's familiarity with space and his ability to put it to work. Some of the credit for this undoubtedly falls to BIS. Congratulations on your many achievements. Good luck for the next 60 years!

Mike Blackwell
Press & Publicity Manager

From: JPL

The British Interplanetary Society has advocated the exploration of space and space exploration for sixty years. On this anniversary I extend to the members of the Society my congratulations for sustained achievement and best wishes for future success.

Edward C. Stone
Director

From: Logica Space and Communications Ltd

Logica takes great pleasure in extending our congratulations to the British Interplanetary Society on the occasion of its 60th anniversary. We have, as a company, been extremely pleased to have been associated with the Society and its activities.

The British Interplanetary Society has long been associated with ideas and opinions at the forefront of space exploration and development, ideas and opinions which have so often led into exciting realities. The UK space industry looks to the Society to continue its good work in bringing together those sectors of society who are able to influence the direction of space development and exploration.

I have no hesitation therefore in anticipating that the next sixty years will be both as interesting and productive as the last sixty, and long may it continue.

Laurence Julien
Managing Director

From: IAF

On behalf of the International Astronautical Federation, of which the BIS is a founding member, I am very pleased to congratulate the British Interplanetary Society in its 60th anniversary. It was indeed necessary to have vision and also a certain kind of courage to promote such a Society in 1933.

Perhaps what has been accomplished in this time is less than the brave founders of the BIS dreamed of. But it is also worth noticing the progress achieved, and perhaps the fact that peace between the two superpowers was achieved, in part, thanks to the development of space science and exploration.

Today we are in the middle of another battle, as essential for mankind as the former. The climatic change and

on its 60th Anniversary

its effects on us can only be properly monitored from space and, if possible, its impact reduced, thus the importance of Mission to Planet Earth. But such an important endeavour cannot put a stop, maybe only reduce the pace, to explore and to conquer, in the most noble sense, our outer space and its celestial bodies. It is there where the future of the human race lies, and it is there where the members of the BIS with their enthusiasm, competence and stamina have won our admiration.

Keep doing your good work.

Alvaro Azcarraga
President

From: AIAA

On behalf of the American Institute of Aeronautics and Astronautics, it is with great pleasure that I extend our warm congratulations to the British Interplanetary Society on the occasion of its sixtieth anniversary. Always an inspiration to the AIAA and its predecessors, your organisation has been instrumental in advancing our knowledge of the universe around us.

The past six decades have seen space exploration grow from a fantastic dream to an every day reality, and the British Interplanetary Society has been there to encourage every breakthrough, document every achievement, and provide encouragement for the next step. Regarded in the highest esteem by the leaders in our field, you have been an inspiration to us all.

Now as we face some of the greatest challenges to test us in our quest to continue this great exploration, we look to the future and know that the vision and leadership of your membership will enable us to further expand the role that humans will play in space.

Brian H. Rowe
President

From: IEE

Congratulations to the BIS on its 60th anniversary, on behalf of the members of the Institution of Electrical Engineers. The Professional Group Committee on Satellite Communications is very aware of the importance of space, and we are proud to be associated with a technology which has not only seen fulfilment of Arthur C. Clarke's vision of 1945, but has surpassed all expectations.

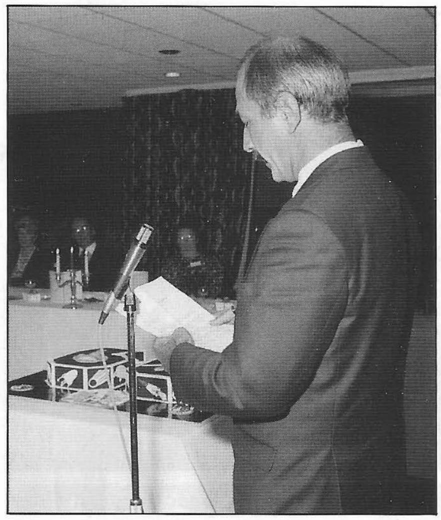
We wish the BIS all good wishes for a further exciting 60 years.

Tim Tozer
Chair, IEE Professional Group E9
(Satellite Communications)

Message from ESA

Societies that play an active role in shaping opinions towards space exploration and exploitation are relatively young, and the British Interplanetary Society holds an honoured place in the genre as it celebrates its diamond jubilee.

In the 1930's it was a bold group of enthusiasts who saw a future beyond the ground-based observatories. It is not idle speculation, however, to suggest that even the most enthusiastic members could not have anticipated that by the 60th anniversary, humans would have walked on the Moon, Halley's Comet would have revealed its secrets, and astronomers would have recorded light more than 13 billion years old.



ESA scientist astronaut Wubbo Ockels addresses the SPACE '93 Anniversary Banquet and brings a message of congratulations from the Director General of ESA.

I and my predecessors have always received the strongest possible support from the BIS, and I would like to thank the staff, and the committee for the positive attitude that they have taken. If I single out Len Carter, I know members will forgive me, for he has, since the early days of ESRO, made sure that there has been enthusiasm for the European dimension in space research.

At the present time, when recession and sharp political changes dominate the European scene, it is very essential that the role of space research does not lose significance; that its long-term importance, especially to the fundamental knowledge of the universe, and our solar system, should remain firmly in the minds of the decision makers and public alike.

The British Interplanetary Society has played its part in the past, and in wishing its members "happy birthday", I know that they will continue to believe in space research and that they will press for a future as invigorating, and as dynamic as the last sixty years.

Jean-Marie Luton
Director General, ESA

We have also received many Messages of Congratulations from Members and Fellows of the Society, similar to those reproduced below, which we greatly value, and to whom we extend our most grateful thanks.

From: James J. Harford, Executive Director Emeritus, AIAA

Forty years ago, in October, 1953, I was hired as Executive Director of the American Rocket Society by Fred Durant, then the President. I was told at the time that if the ARS advanced the cause of space exploration in the US nearly as effectively as the BIS did, I could probably keep my job.

So I spent my career trying to keep up with Len Carter et al. It always bothered me that ARS did not have the courage to keep the name American Interplanetary Society, which it actually had at its founding in 1930. But then we joined the aeronautical guys in 1963 and would have lost the name anyway.

Here's to the BIS on its 60th anniversary. I'm proud to be a Fellow, and I hope to be around for the celebration of the 75th with a Mars landing.

From: Pierre-Emmanuel Paulis, Belgium

I have been a member of the BIS for many years and I would like to wish you a good anniversary on 15-17 October. I would like to have met Edwin Aldrin, but it is not possible for me to come to Hastings. It is indeed an honour for the BIS to receive this famous US astronaut. Congratulations for 60 good years and for your very interesting ***Spaceflight*** magazine.

From: David K. Whittock, France

Congratulations on the occasion of the 60th Anniversary of the foundation of the British Interplanetary Society.

You are to be congratulated, too, on the excellent standard of your publications, which make most interesting and informative reading.

Continued success in the future.

From: Michael Münter, Denmark

Congratulations to you all with the 60th anniversary. Hope you have an enjoyable weekend in Hastings.

Hastings:

15-17 October 1993

Above: The Society's special guest Buzz Aldrin arrives at Hastings during a spell of fine sunny weather which greatly added to everyone's enjoyment of the weekend.

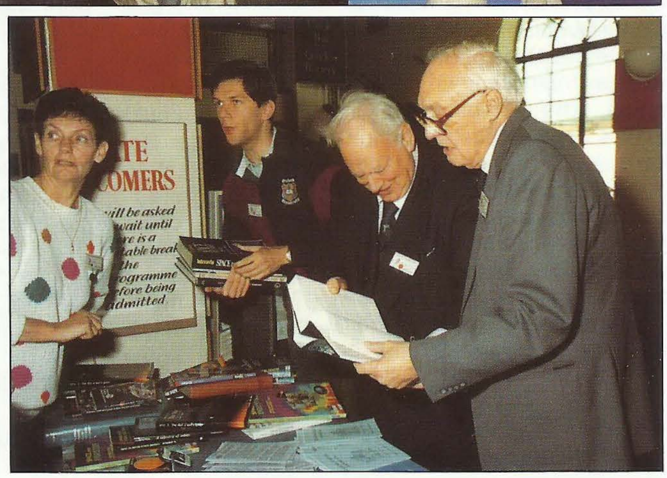
Below: The Right Worshipful the Deputy Mayor of Hastings, Councillor Mrs Gladys Stewart welcomes participants at the opening of the 'Space Initiatives' Conference on 16 October. On the left is the Society's President, Mr A.T. Lawton.

Left: Buzz Aldrin seated in the auditorium of the White Rock Theatre raises his arm to acknowledge a greeting from the participants.

Below: BIS Council Members Bob Parkinson and Mark Hempsell in discussion with Bill McLaughlin of JPL at the BNSC Space Exhibition.

Bottom Right: Patrick Moore and Len Carter spend an interesting moment perusing the books at the BIS sales stand in the foyer of the White Rock Theatre.

Below: At the Marina Pavilion for the Civic Reception: Left Mr A.T. Lawton (BIS President), Mrs F. Fry, Mr M.R. Fry (BIS Vice-President) Mrs A. Lawton, Councillor Richard Stevens (Mayor of Hastings) and Dr Patrick Moore.



SPACE '93

Organised by the British Interplanetary Society on the Occasion of its 60th Anniversary

Main Events

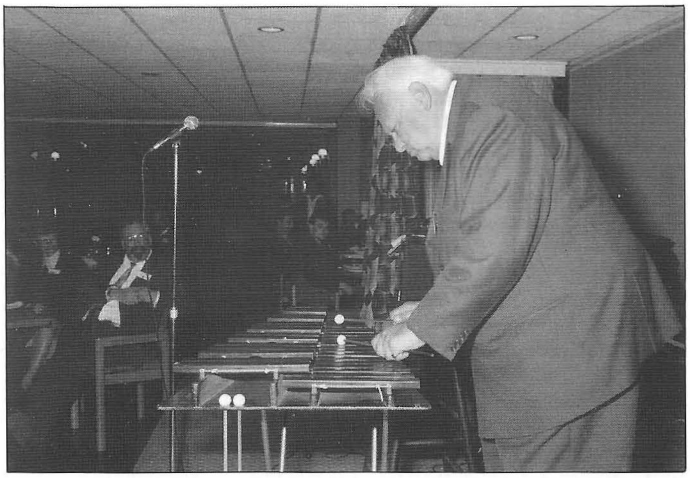
At the Marina Pavilion

Civic Reception	**15 October**
Anniversary Dinner	**16 October**

At the White Rock Theatre

'SPACE INITIATIVES'	**16-17 October**
Satellite Link-Up	**17 October**

Councillor Richard Stevens (Mayor of Hastings) welcomes participants to Hastings at the Civic Reception.



An entertaining interlude to the evening was provided by Patrick Moore with his xylophone.

Civic Reception

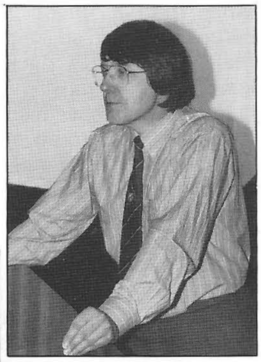
Formalities were kept to a minimum and participants were soon into the swing of an informal get-together with the opportunity to renew friendships and make new acquaintances. An entertaining speech of welcome from the Major of Hastings and response from the Society's President set the tone and, with buffet and bar facilities on hand, informality prevailed. Not entirely impromptu was Patrick Moore's arrival on stage however where, after a few characteristic quick-fire words, he rolled in a xylophone and brought his musical skills to bear to the delight of all.

'SPACE INITIATIVES'

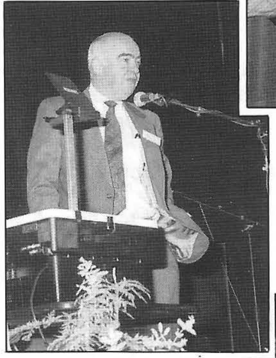
A main event of SPACE '93 was the two-day conference held in the auditorium of the White Rock Theatre, Hastings. Leading authorities provided extremely informative accounts of work in their particular fields and questions from the audience readily filled the discussion time available.

List of Speakers

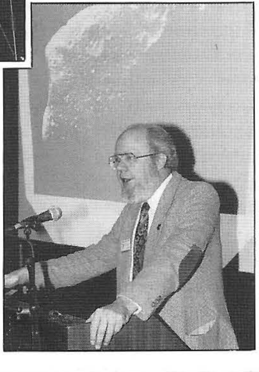
Overviews	
A.T. Lawton	Welcome to Space '93
J. Leeming	The Current Space Scene: A Realistic Appraisal
W.I. McLaughlin	International Space at JPL
G. Naja	The European Space Agency and its Long Term Space Plan
H.J.P. Arnold	Memories of Space: Images from Afar
Exploring the Planets and Beyond	
G.S. Tilford	Mission to Planet Earth
W.R. Claybaugh II & M. Griffin	A Lunar Return Programme Plan *(Read by C.M. Hempsell)*
M.J. Fogg	Future Life on Mars - The Advantages of Terraforming
Space for the Benefit of Mankind	
P.T. Thompson	International Satellite Communications: Past, Present and Future
D.G. Fearn	International Collaboration in Electric Propulsion: The Artemis and Topaz Missions
New Space Concepts	
C.M. Hempsell	The Space Station and Beyond
A. Bond	A Traveller's Guide to the 21st Century Space Times
D.R. Helas	Progress on the AN225/HOTOL Launch Vehicle Concept
R.C. Parkinson	Scenarios for International Collaboration on Future Reusable Launch Vehicles
R.A. Rowntree	Future Developments in Tribology
Ways and Means	
D.J. Shapland & F. Rossitto	European Manned Space Programmes - Crew Arrangements
C.E.S. Horsford	International Control of Outer Space: Present and Future
D.E.B. Wilkins	Mission Control in 2023
P. Norris	Successful Industrial Collaboration for International Space Initiatives



Alan Bond
Reaction Engines Ltd



Dr G.S. Tilford
NASA, Mission to Planet Earth



Dr W.I. McLaughlin
JPL

(Photos of speakers by courtesy of H.J.P. Arnold, Space Frontiers Ltd.)

After Voyager What Next?

These past 25 years have been a spectacular period for space exploration when we have systematically sent spacecraft to visit each of the planets from Mercury to Neptune. In these few years, which is an infinitesimally small time when compared with human life on this planet, we have transformed our understanding of the worlds around us and placed the Earth in its true perspective.

BY GARRY HUNT
Fellow of the BIS

There is no doubt, that one of the most significant contributions to the advancement of our knowledge has come from the Voyager missions to the outer planets. These missions have been the colossus of space exploration. They were conceived with imagination, engineered with precision, supported by teams of dedicated engineers who constantly overcame numerous problems. They brought together a talented set of international scientists, who not only made some amazing discoveries of the distant words in the outer depths of our solar system, but also learnt the importance of communicating to the public, so that everyone could share in this new knowledge, in the comfort and warmth of their fireside armchairs.

Many people are unaware that the design of the missions had an element of chance; for it was a young CALTEC summer student, who in the mid 1960s, discovered a forthcoming unique planetary alignment and suggested that a special sling-shot passage of a spacecraft from Jupiter, to Saturn, to Uranus and then finally to Neptune, would be possible, in a mere 12 years.

At an overall cost of just 25c per American per year, the Voyager mission to the outer planets has been the star in the NASA planetary programme. More than 16 years after launch, and a journey of more than 4 billion miles, the space probes are still sending back information that has pushed back the frontiers of knowledge. Voyager's list of discoveries is almost endless. Numerous new satellites were discovered around each of the planets; then volcanoes on Io, the hydrocarbon smog and nitrogen veiled world of Titan, the mysterious Miranda and tantalising Triton, new ring structures around Jupiter, Uranus and Neptune. Now after several centuries, that *whirlpool of emotion* the Great Red Spot of Jupiter, is no longer the subject of after dinner speculation. Today we can view the apparent chaos of the turbulent cloud systems of these gas giants with some degree of understanding.

Political issues and battles for funding are all too familiar to scientists trying to defend the value of adding more and more data. But for what purpose? Was Richard Feymann right when he said *"...With more knowledge comes a deeper, more wonderful mystery, luring one on to penetrate deeper still.."* But the financial costs of scientific failure have risen since the time when Archimedes made such valuable use of a bath, Galileo of balls of different weight and Newton of an apple.

Alas the world space programmes have waned over the past two decades since the adventurous Apollo missions to the Moon, the Viking mission to Mars, and the brilliantly successful Voyager Grand Tour. All scientists dream fantastic dreams, but space scientists are more exposed to failures than their laboratory bound colleagues. Space missions involve pitting computer aided intelligence against hugely hostile planetary environments.

Some years ago, when the Space Shuttle missions were beginning, they were so novel that the launches were covered live on ITN. They rarely performed on time, so we were often on the air, live and unscripted, for several hours. During one launch programme, when I worked with Dave Scott, the Apollo 15 Commander, I asked him, *"..what was the most dangerous part of going to the Moon...?" He quickly replied, "..lying in the spacecraft on the pad, hearing the engines fire, and knowing that everything under you has been built by the lowest bidder..."* But we must remember, there cannot be any short cuts in the development of any component without cataclysmic effects. The difference between success and failure may be small in actual financial costs, but the impact of a space failure and the associated public visibility it creates, is huge.

The road on which science advances is slow and studded with failures, some instructive and some merely frustrating. The recent loss of the Observer Mars Probe is tragic, but it follows on the defects in the Hubble Space Telescope and the problems with the Galileo spacecraft now en route to Jupiter. Hopefully these problems are no more than a small step back for mankind, as NASA and the space programmes in general, develop the way forward.

There is still much to do, not only to improve our understanding of the worlds around us, but also to help improve our own life on Earth and our management of this fragile planet. The next few years are taken up with the Galileo probe, which we hope will provide dramatic insight into the structure and composition of the Jovian atmosphere. Will we find that the Arthur C. Clarke's vision in 2001 was correct? Then the Cassini mission heralds the 21st Century by unveiling the secrets of the atmosphere and the surface of Titan. Will the European Probe finally tell us whether the surface of Titan is solid, or mountainous or an even giant ocean, while the NASA orbiter continues to circle Saturn, studying the planet's atmospheres, rings and numerous satellites?

But we have still not answered the age old questions of how the planetary systems were formed and whether there is, or has been in the past, life on other planets. Mars is central to this discussion and the question will never be properly answered until we have fully explored the surface of the planet which will certainly involve setting up Mars bases and sending men and women to work there. Viking provided excellent but often ambiguous pictures of the surface of Mars. Since then debates have centred on the sculptured rock, the so called *Face of Mars*, purporting to suggest evidence of past life on the planet. Why do the media concentrate on these silly issues when there is so much more important information on space and science, to communicate to the public? Certainly this type of discussion does not improve the credibility of scientists in the eyes of the public.

The planetary missions of the last 25 years have shown that the Earth is unique and our island home is no more than a *cosmic speck* amongst the stars. Future missions to increase our understanding and also assist us in managing the Earth's limited resources, will require more elaborate visits to Mars and further probes to the outer planets. Mars, for example, is an excellent laboratory for testing theories of the atmospheric circulation, which is particularly relevant for increasing our understanding of the role of the biosphere and atmospheric change on the Earth.

But all these missions are going to be increasingly more expensive and in competition with other pressing needs for Government funding. Money for such missions will always be difficult to obtain and every Government will try to limit the funds available. Consequently, no nation can go it alone. We have now seen Western nations come to the rescue of Russia's Mars programme, so perhaps the stage is set for greater cooperation between the space agencies. The magic of space which has enriched our daily lives for several decades, and increased our understanding of the world around us and the Earth in particular, could be regenerated by a new, exciting era of cooperation.

We must make sure that the scientific community communicates their work to the public in a way that Joe public understands. The man in the street has a right to know what is happening and what has been learnt. The public are interested, as we can see from the presence of Stephen Hawking's *Brief History of Time*, as it continues to break records in the Best Selling Book charts.

For more than 60 years, the British Interplanetary Society and its energetic members have been untiring in promoting every aspect of space exploration. Events such as SPACE '93, are a further excellent example of the imaginative way the Society continues to stimulate international cooperation and discussion on space matters. Long may these activities continue. Mr President, on behalf of the guests, thank you for your kind and generous hospitality, and may I wish you and the BIS every success in the future.

60th Anniversary Banquet

Above: Guest speaker Prof Garry Hunt delivers his after-dinner address entitled *After Voyager What Next ?* On the table in the foreground is the Society's 'Birthday Cake'. The two cakes, shaped as 60, were elaborately decorated with spacecraft designs.

Left: Seated among the participants at this table is ESA scientist astronaut Dr Wubbo Ockels (second from the right).

Right: After the formal speeches Buzz Aldrin and Patrick Moore answered participants' questions, during which time Buzz Aldrin recounted his experiences as a lunar astronaut.

Below: Buzz and Lois Aldrin chat with the participants. In this group are, left to right, Suszann Parry, Lois Aldrin, Ray Ward, Buzz Aldrin and Penny Wright.

Toasts and Speakers

The Loyal Toast	-	Proposed by The President
The Borough of Hastings		
	-	Proposed by The President
Response	-	The Right Worshipful, The Mayor of Hastings Councillor Mr Richard Stevens
To The Society's Founder, Mr P.E. Cleator		
	-	By The President
Our Distinguished Guests		
	-	Proposed by The President
Response		*After Voyager What Next?*
	-	Prof Garry Hunt

Honour for Dr W.I. McLaughlin

In a short address the Society's Vice-President Mr Martin Fry said:

"We are awarding the Society's Bronze Space Achievement Medal to Dr W.I. McLaughlin in recognition of virtually a lifetime's work dedicated to space. He has had a distinguished career, particularly at the Jet Propulsion Laboratory which he joined in 1971 and subsequently worked on the Viking, SEASAT, IRAS and Voyager projects, serving as the Engineering Manager for Voyager's flyby of the planet Uranus. He then managed the Mission Profile and Sequencing Section at JPL for six years and is now Deputy Manager of Astrophysics and Fundamental Physics Preprojects at the Laboratory.

He is also noteworthy for numerous texts and articles promoting space on the widest possible level and for his contributions to the basic rationale of space. Dr McLaughlin has regularly written "Space at JPL" for ***Spaceflight*** since 1982.

All this adds up to a pattern of achievement outstanding in its dedication, in its thoughtfulness and in its application".

Arthur C. Clarke in Hastings - Sri Lanka Satellite Link-Up

On Sunday 17 October the SPACE '93 programme was highlighted by a video link-up with Arthur C. Clarke in Sri Lanka. Arthur first proposed the concept of geostationary communications satellites to a select group of the Council of the BIS several months before its publication. Consequently it was a unique event for the BIS and its former President to be linked up in this way to commemorate the 60th Anniversary.

An entertaining hour for the SPACE '93 audience in the Sussex Room of the White Rock Theatre with Arthur C. Clarke appearing on the large TV screen and recounting historical space events and future activities. Patrick Moore is seen here claiming his wager of a bottle of wine.

Patrick Moore was the first guest to converse with Arthur and reminded him of a long standing wager that Arthur would not write any more science fiction novels. Arthur conceded that he had lost the wager many times over and fulfilled his obligation with honour when his brother Fred Clarke presented Patrick Moore with the result of the wager which was a bottle of white wine.

The next honoured guest to remind Arthur of their common interests was Buzz Aldrin. Then Dr W.I. McLaughlin from the Jet Propulsion Laboratory (JPL) exchanged a few words with Arthur.

During the first part of the link-up historical space events and future activities were discussed with an interesting review of the likelihood of the predictions in *'2001 - Space Odyssey'* actually becoming a reality in that year. Arthur admitted that he may have got the timing slightly wrong but was adamant that his prediction will actually happen.

Arthur was very keen to respond to questions from participants and a queue soon developed for those with questions to pose. Sadly the hour quickly slipped away but not before a nostalgic conversation between Arthur and his colleague of long standing, Len Carter. Arthur was clearly moved when Len recounted their years together at the Greys Inn Road HQ of the Society back in the 1940s.

The link-up, sponsored by BT, Intelsat and Eutelsat operated over a double satellite hop. The first was via an Intelsat VI satellite located at 60°E. Signals were received at the BT Earth station in Madley and then sent via a Eutelsat I satellite (21.5°E) down to a 2.4 metre transportable BT terminal at Hastings. It was organised through the good offices of Dr Paul Thompson, BIS Council Member and staff member of Global Networks, BT.

The proceedings concluded with a buffet lunch and the gift of a commemorative beaker for each participant provided courtesy of British Telecom.

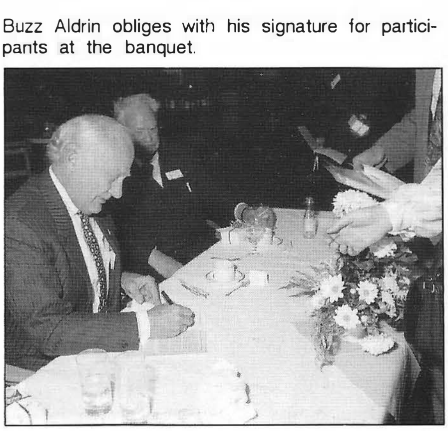
Video: Plans are in hand for the preparation of a video of the satellite link-up to be available shortly.

To All Who Contributed to the SPACE '93 Anniversary Event

The BIS Council extends its grateful thanks to all those who provided assistance in making SPACE '93 an extremely enjoyable and worthwhile event. To:

- The Borough and Corporation of Hastings for their magnificant hospitality.
- Our special guests: Mr Buzz Aldrin (Lunar astronaut, holder of the Society's Gold Medal and BIS Member), Dr Patrick Moore (Fellow and Amateur Astronomer), Prof Garry Hunt (Fellow and Space Consultant) and Dr Wubbo Ockels (ESA scientist astronaut) for their enthusiastic participation.
- To the Speakers at the 'Space Initiatives' conference for the careful attention that they gave to their presentations.
- To the sponsors of the satellite link-up: BT, Intelsat and Eutelsat and all those involved with these arrangements.
- To BT and Logica Space and Communications Ltd for sponsorship of courtesy items to participants.
- To many individuals who helped in innumerable ways particularly to:
  - Eric Waine and Norman Nicol for projectionist assistance.
  - 'Douglas' (H.J.P.) Arnold for providing special projection equipment.
  - Clive Simpson for help with press arrangements.
- To the Society's staff for splendid organisation of the detailed arrangements involved, particularly to Ms Shirley Jones (Executive Secretary) and Mrs Suszann Parry (Deputy Executive Secretary).

Buzz Aldrin obliges with his signature for participants at the banquet.



Society staff members left to right are Bernadette Walsh (standing); and seated are Marilyn Marsland, Shirley Jones, Suszann Parry, Len Carter and Mary McGivern. Standing is Ben Jones who assisted at the event.

Bouquets for the Executive Secretary (Shirley Jones) and the Deputy Executive Secretary (Suszann Parry) in recognitiion of their services in the organisation of SPACE '93.

Eleven Day Mission with EVA

STS-51

The STS-51 crew holds up five fingers on one hand and one finger on the other to designate the number (51) of their flight. The five-member crew enjoyed a smooth touchdown in the Space Shuttle orbiter Discovery with KSC's first night landing. Main gear touchdown was at 3:56:07 am EDT on September 22, 1993. From left are Mission Secialist Daniel W. Bursch, Pilot William F. Readdy, Commander Frank L. Culbertson Jr., and Mission Specialists James H. Newman and Carl E. Walz. *NASA*

A primary objective of the STS-51 mission was the deployment of the Advanced Communications Technology Satellite (ACTS) and its Transfer Orbit Stage (TOS) booster. ACTS/TOS is the latest in NASA's series of advanced communication satellites and a test-bed for technology which will be used in future operational satellites. Also, the Orbiting Retrieval Far and Extreme Ultraviolet Spectrometer-Shuttle Pallet Satellite (ORFEUS-SPAS) was carried for deployment and retrieval during the mission.

BY ROELOF L. SCHUILING
at the Kennedy Space Center

STS-51 Countdown

On September 9, ground crews began the final storage of middeck and flight deck supplies and payloads. They also performed microbial sampling of the flight crew's drinking water and checked water levels in the waste management system.

During that afternoon the STS-51 flight crew arrived at the Kennedy Space Center's Shuttle Landing Facility after having flown in from their base at the Johnson Space Center in Houston, Texas.

On September 10, technicians completed final vehicle and facility closeouts and began activating the orbiter's communications systems and configuring Discovery's cockpit for flight.

Following their breakfast, the crew received a briefing on weather conditions at KSC and around the world, then put on their partial-pressure flight suits and left their quarters at about 4:30 am to be driven to the launch pad and begin entering Discovery at about 5:00 am.

The last two built-in-holds were 10 minutes in duration and came at the T-20 and T-90 minute points. During the final hold, the flight crew and ground team received the NASA Launch Director's and Mission Management Team's final "go" for launch.

Flight Day One

Following their 7:45 am EDT launch on September 12 and their arrival on-orbit, Discovery's crew prepared their spacecraft for mission operations. The payload bay doors were opened to expose the mission payloads and the orbiter's radiators to space. Checkout of the Advanced Communications Technology Satellite/Transfer Orbit Stage (ACTS/TOS) payload came at approximately 10:25 am (all times are KSC times). At 2:20 pm the ACTS/TOS was elevated in preparation for the satellite's deployment which was then planned for 3:43 pm.

The first attempt to deploy the ACTS/TOS was delayed by the crew when two-way communications with Mission Control were lost about 30 minutes prior to scheduled deployment. Flight controllers at Mission Control could receive telemetry and voice from Discovery, but the crew could not receive communications from the ground.

The crew reconfigured the orbiter's S-band communications system to a lower frequency and restored two-way communications with the ground. Two-way communications had been out for about 45 minutes. After consulting with the crew, flight controllers began planning for a second deployment attempt. A second deploy attempt had not been originally planned for the first mission day to avoid a possible high crew work load on that day, however mission commander

About the Crew

STS-51 was commanded by Frank L. Culbertson, Jr., 44, Capt., USN who was making his second space flight. He flew on STS-38 in November 1990 as pilot. The STS-51 pilot, William F. Readdy, 41, was also making his second space flight as he had flown on STS-42 in January 1992.

Mission specialist 1 was James H. Newman aged 36. Daniel W. Bursch also 36 and Commander, USN was mission specialist 2. Carl E. Walz, 37, Major, USAF, was mission specialist 3. All of the STS-51 mission specialists were making their first space flights.

Pilot William F Readdy, centre, looks at some minor tile damage on the thermal protection system (TPS) tiles following Discovery's landing at KSC's Runway 15. *NASA*

Frank Culbertson told Mission Control that he and his crew were "100 percent" ready to proceed with the longer day and the decision was made to go ahead with the deployment.

The ACTS/TOS deployment was then accomplished at 5:13:29 pm. Forty-five minutes later the TOS booster stage fired on time and ACTS satellite controllers reported that their satellite was in excellent shape and in its planned orbit.

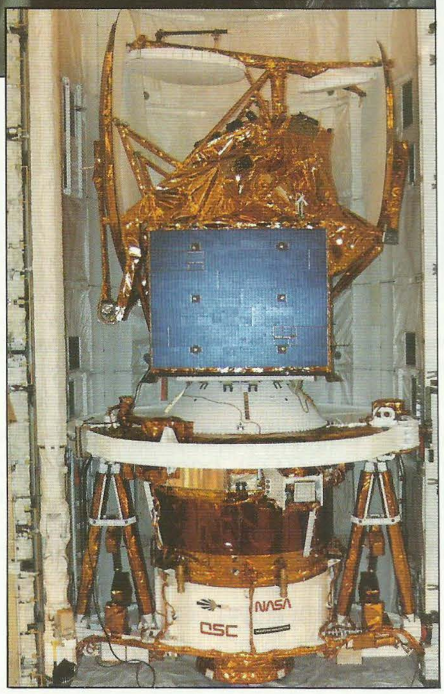
The crew also checked-out Discovery's robot arm in preparation for the deployment of the ORFEUS-SPAS on mission day two and activated the middeck Radiation Monitoring Equipment.

Due to their longer work schedule for the first day the crew began their sleep period at 7:15 pm - a half hour later than planned.

Flight Day Two

Mission Control awakened the STS-51 astronauts with a recording of Elvis Presley's song "Please Release Me" in honour of the deployment release of the Orbiting Retrievable Far and Extreme Ultraviolet Spectrometer-Shuttle Pallet Satellite (ORFEUS-SPAS) scheduled for the second day of the mission.

The crew performed an altitude adjustment burn of the manoeuvring system engines to optimise landing opportunities at the end of the mission and then turned to the major activity of the day - the deployment of ORFEUS-SPAS. Mission specialist Dan Bursch used the Discovery's robot arm to hold the satellite in preparation for removing ORFEUS-SPAS from the payload bay. The flight crew and mission controllers then performed a complete checkout of the satellite's systems as



Inside the cargo bay the primary payloads of STS-51 are ORFEUS-SPAS (upper) and ACTS-TOS (lower). *NASA*

it was held by the robot arm.

The release of the satellite was delayed one orbit to allow for the completion of the checkout of all of its instruments and ORFEUS-SPAS was released at 11:06 am on September 13. Following the release, spectacular views of Discovery were beamed to Earth as an IMAX high resolution camera aboard ORFEUS-SPAS photographed the orbiter. The IMAX camera caught Discovery's separation burn and views of Discovery as it crossed the Earth's limb, moved across the path of the satellite and passed from darkness into sunlight. The camera also captured photographic footage of the orbiter as it rotated through 360 degrees about 600 feet in front of the satellite.

With the completion of the IMAX photography, Discovery was manoeuvred away from the satellite. Later, the satellite's scientific investigations began to acquire data on the life-times of stars by measuring some of the coldest and hottest matter found in our galaxy. As the crew prepared for their second sleep period in space, Discovery was about four nautical miles ahead of the satellite and moving farther away at a rate of about two nautical miles per orbit.

Flight Day Three

The crew were awakened at about 1:45 am for a day of work concentrating on the secondary payloads located in the Shuttle's middeck area. Work began with several of these experiments, including the Commercial Protein Crystal Growth (CPCG) experiment and the Investigations into Polymer Membrane Processing (IPMP).

The CPCG explores the structure of specific protein molecules in space-grown crystals while the IPMP researches the mixing of various solvent systems in the absence of convection

Discovery is rolled into the Vehicle Assembly Building for mating with the external tank and twin solid rocket boosters in preparation for STS-51. *NASA*

and demonstrates technology that can be used to regulate the porosity and uniformity of polymer membranes.

The crew sent down additional spectacular video images of the ORFEUS-SPAS taken the day before as Discovery moved away from the satellite. Meanwhile, aboard the satellite scientific investigations had already started. The orbiter was 30 to 40 nautical miles away from the satellite and Discovery fired its thrusters twice during the day to maintain the desired separation distance. Discovery was also acting as a communications relay between the satellite and the ground. A new piece of equipment making a debut on STS-51, the Extended Range Payload Communications Link (ERPCL - pronounced "ehrpickel") allowed the orbiter to perform the relay function at greater ranges than it could previously.

Mission commander Frank Culbertson and mission specialist Daniel Brusch used the stationary bicycle in the middeck area to continue the study of the effects of aerobic exercise on the body in weightlessness. The crew also monitored the Chromosome and plant Cell Division in Space (CHROMEX) experiment in the middeck.

Discovery's cabin pressure was dropped from 14.7 psi - normal cabin air pressure - to 10.2 psi which is approximately what air pressure would be at 10,000 feet altitude on Earth. This was in preparation for the EVA planned for Flight Day Five. The lower pressure allows a crew's bloodstream to be purged of nitrogen in order to prevent possible occurrence of "the bends" when using the 4.3 psi pressurised spacesuits in EVA activity.

Flight Day Four

The primary job for Discovery's crew on their fourth day in space was the checkout of the pressure suits to be worn on the Flight Day Five EVA operation. The checkout is always done the day before the suits are scheduled for use.

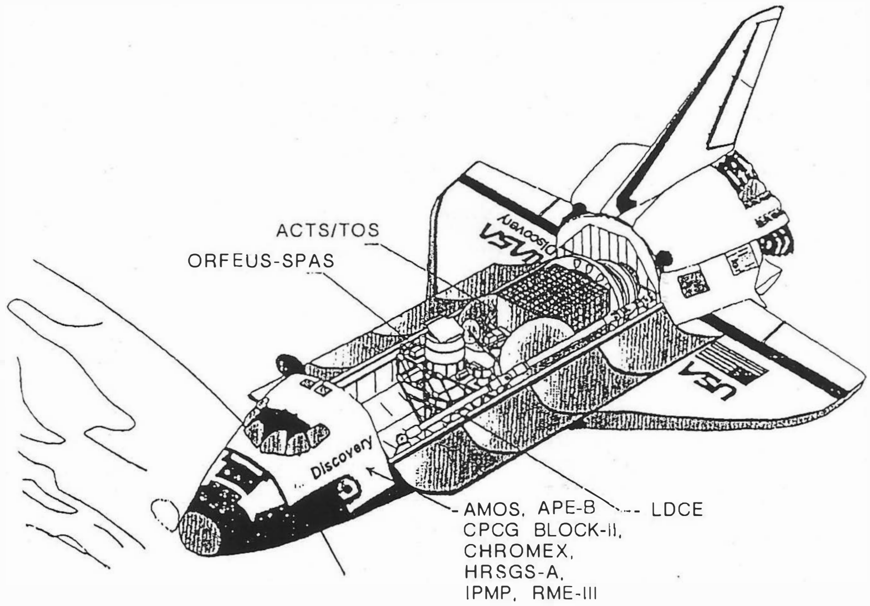
After the suit checkout, crew members took time out for a video-taped interview at 6:20 am. The interview was played over Houston television stations an hour and a half later. Questions covered the double satellite deployment, the upcoming EVA and mission operations.

Flight Day Five

In honour of the impending spacewalk the Discovery crew were awakened by Mission Control with the music "Walk don't run" played by a band of which mission specialist Carl Walz's brother is a member.

The crewmembers had an early start in preparing for the day's EVA operations and mission specialists Carl

STS-51 Cargo Configuration



About the Payload

ACTS will expand the use of satellites in the information age through the use of very small aperture ground terminals (VSAT's) with advanced capabilities. Among the ACTS capabilities are wide geographical area coverage, demand-assignment access, full mesh interconnectivity and service and networking flexibility made possible by integrating voice, data and video operations at rates of 1.544 megabits per second (MBPS). Other experiments will be conducted at rates as high as 622 MBPS in microwave switch mode of operation. ACTS provides the largest transponder throughput ever flown, at 1.0 gigabits per second (GBPS). With three active transponders, it will have a 3 GBPS capacity. ACTS will provide on-demand communications to small 1.2 m Earth terminals.

Among the ACTS technologies are multiple beam antennas to produce spot beams for communication with small ground terminals and to average out geographical demands by multiple hopping beams, onboard processing with demodulation and remodulation onboard the spacecraft, onboard switching, and Ka band technology which will open up a new portion of the radio frequency spectrum for communication satellite use in the United States.

The ACTS booster is the TOS (Transfer Orbit Stage) which is a three-axis stabilised perigee solid upper stage vehicle. The TOS main propulsive element is a solid rocket motor of 92 inches diameter and 124 inches in length. TOS was first used in September 1992 as an upper stage booster for the Mars Observer spacecraft. The TOS is built by the Martin Marietta Astronautics Group for Orbital Sciences Corporation. The solid rocket motor is an ORBUS-21 built by United Technologies Chemical Systems Division and provides 59,000 pounds of thrust for 110 seconds to provide the 22,800 mph velocity for the geosynchronous transfer orbit. The TOS itself provides the solid rocket to place the satellite in its final orbit.

Located just ahead of the ACTS/TOS payload in the Discovery's cargo bay was the Orbiting Retrievable Far And Extreme Ultraviolet Spectrometer - Shuttle Pallet Satellite (ORFEUS-SPAS) payload. ORFEUS-SPAS is a deployable and retrievable satellite designed to provide information on how stars are born or die and the properties of the interstellar medium. The satellite is deployed and retrieved by the Shuttle's Remote Manipulator System during the mission. The payload consists of the SPAS carrier and several instruments. The ORFEUS instrument is an astronomical telescope for studying molecular hydrogen temperatures and densities in dense regions of gas and dust clouds in space; and how these collapse to form stars. ORFEUS is a one-metre telescope equipped with two focal-plane UV spectrometer instruments.

The ORFEUS also contains an instrument for studying the large contrasts in the chemical and physical properties of the interstellar medium by observing UV radiation from hot bright stars and recording how this is altered by various atoms, ions and molecules.

Also contained in Discovery's payload bay and mounted on the bay wall forward of ORFEUS-SPAS is the Limited Duration Space Environment Candidate Material Exposure (LDCE) experiment. The LDCE is contained in GAS canisters with motorised door assemblies which can be opened in space. The objective is to introduce developmental composite materials to a flux of atomic oxygen atoms in low Earth orbit.

Also onboard in Discovery's middeck were the IMAX camera, the Commercial Protein Crystal Growth experiment and the Chromosome and Plant cell Division in Space experiment.

Walz and Jim Newman left the crew cabin and began operations in the payload bay at 4:32 am on September 16. This was about a half-hour earlier than planned. The EVA astronauts completed evaluations of tools, tethers and foot restraint platforms in a study of the applicability of proposed Hubble Space Telescope EVA equipment and procedures. Their findings reassured mission planners for the STS-61 mission that their plans for the on-orbit repair of the Hubble Telescope were sound.

Checking out the preparations for the Hubble repair spacewalk, however, was only a part of the goal of the EVA operation. The astronauts also evaluated the difference between ground training and actual work on-orbit. The two mission specialists were actually ahead of scheduled most of the day and they accomplished more than originally planned. However a balky tool box lid slowed them down as they were cleaning up and the EVA took about 45 minutes extra. The total time of the EVA was seven hours, five minutes and 28 seconds.

After the spacewalk, Discovery fired its engines to stop the gradual drift away from the ORFEUS-SPAS satellite. Discovery was about 62 nautical miles ahead of the satellite at that point and began closing the distance at a rate of about two miles per orbit.

Flight Day Six

The crew spent much of their sixth day on orbiter manoeuvres to begin the rendezvous with ORFEUS-SPAS for the satellite's retrieval. At about 6:20 am Discovery passed 21,000 feet directly above ORFEUS-SPAS and moved into a position well behind the satellite at a range of about 15 nautical miles.

Flight Day Seven

Astronauts Walz and Newman continued the study of the glow phenomenon experienced around orbiter surfaces due to interactions with atomic oxygen in the rarefied atmosphere. The two astronauts operated the APE and HRSGS experiments during the periods when the orbiter was on the dark side of the Earth and out of the Sun's light.

The crew fired Discovery's thrusters to begin the approach to ORFEUS-SPAS for the retrieval which was set for the following day. When the crew went to sleep Discovery was about 46 nautical miles behind the satellite and gradually narrowing the distance.

Flight Day Eight

The crew awakened at 10:25 pm Saturday September 18 with the retrieval of the ORFEUS-SPAS as the major objective of the day. First, however, the LDCE experiment in the payload bay was deactivated in preparation for the mission's scheduled end.

The rendezvous sequence began at about 2:30 am on the 19th with Discovery about 37 nautical miles behind the satellite. The crew fired the orbiter engines and over the next three hours moved to within 8 nautical miles of the satellite, at which distance the satellite was in view of the electronic star trackers on the nose of Discovery.

At 5:38 am the Terminal Initiation burn of the engines took place as scheduled, followed by a few minor thruster burns to adjust the terminal approach path. The orbiter's Ku-band antenna, together with the radar system, had a lock on the satellite. Mission commander Frank Culbertson took over manual control of the rendezvous and Discovery passed about one mile below ORFEUS-SPAS. Culbertson flew the orbiter's approach to within 35 feet of the satellite. During the manual approach two laser ranging devices - one remotely operated from the payload bay and one operated through Discovery's windows by pilot Bill Readdy - assisted by providing range and closing rate data which supplemented the radar system.

Actual capture of the satellite by the robot arm was accomplished by mission specialist Dan Bursch at 7:50 am. Bursch then used the arm to move the satellite through a series of 11 different positions so that the IMAX camera on the satellite could photograph Discovery from a number of angles. Next, with Discovery's steering thrusters turned off, Bursch moved the arm through a series of tests designed to provide information to assist in planning a future Discovery flight that will carry the Wake Shield Facility - a payload that will be moved about on the Shuttle's robot arm. Bursch then brought the satellite back into the payload bay and latched it securely.

After the satellite retrieval operation, Discovery's crew turned off one of the fuel cells in a test designed to gain information to be used on future missions when Shuttles dock with a space station and turn off their electricity generating systems for long periods. The fuel cell was turned back on the following day. Meanwhile the other two fuel cells continued to provide electricity for the mission.

After completing the day's activities Discovery was in a 165 by 142 nautical mile orbit, circling the Earth every 90 minutes and 17 seconds.

Flight Day Nine

The Discovery crew were awakened by Mission Control using the recorded sounds of the astronaut band "Max-Q" with Carl Walz serving as lead singer.

In addition to restarting the shutdown fuel cell, the crew conducted preparations for their return to Earth which was then set for the following day. Mission commander Frank Culbertson and pilot Bill Readdy checked the orbiter's flight control surfaces and thruster jets to ensure they would be ready to support the landing. One of the thruster jets failed and another showed an incorrect chamber pressure sensor but neither problem would affect the operations as several other thrusters were available on each side as backups.

Later in the day the crew performed the stowage operations and readied the spacecraft for its return to Earth. Two landing opportunities were available for the scheduled end of the mission on Tuesday September 21; one on orbit number 143 and one on orbit 144. Both of these were at the Kennedy Space Center, however additional landing opportunities were available at California if required.

Flight Day Ten

Low level clouds and rain showers within the limit of 30 miles prevented the landing of Discovery on its scheduled return day of September 21. In view of a dynamic weather forecast for Florida for the 22nd, mission managers made the decision to extend the STS-51 mission one additional day. They would then shoot for a landing at the Kennedy Space Center as the prime location.

Two landing opportunities existed at both Florida and California on the 22nd; however, all would be night landings in the early morning hours of the 22nd.

The flight crew had a relatively easy day and began their last sleep period at 1:00 pm and awakened at 9:00 pm on the 21st.

Flight Day Eleven

Following their last "morning" in space the crew of Discovery concluded their final preparations for landing. The weather was acceptable at KSC and at 2:55 am on the morning of the 22nd the deorbit burn of the manoeuvring engines was initiated.

The deorbit burn went well as did the Discovery's reentry from orbit and approach to the Kennedy Space Center. Discovery and her five member crew touched down safely on KSC's runway 15 at 3:56:07 am. This was the first nighttime shuttle landing ever made at the Kennedy Space Center. The orbiter touched down 2,150 feet from the threshold and rollout distance was 8,350 feet.

After undergoing routine medical checks and meeting with their families, the flight crew later returned to Houston.

The orbiter had travelled over 4.1 million miles during the STS-51 mission. After the crew left the orbiter, Discovery was towed from the landing area at 7:30 am and was moved inside the Orbiter Processing Facility bay 3 by 8:40 am.

Correspondence

Competition Winner

Sir, I was very pleased with the video tape that I won in the Space Shuttle Competition. May I compliment you on an excellent magazine, that I always look forward to. ***Spaceflight*** is one of the few magazines that still gives us plenty of information about the interesting subject of space research.

During the twenty years or so since I became a member of the BIS, ***Spaceflight*** has always been one of the main sources of information for me. Keep up the good work!

W.P. HOLWERDA
The Netherlands

Sir, Now that the change from the stylish NASA 'worm' emblem to the old-style 'meatball' is a *fait accompli*, I thought the readers of ***Spaceflight*** might like to see the new livery of the astronaut's T-38 jets featuring the vector and orbit portions of the 1960's era emblem. I photographed the T-38's upon arrival of the STS-51 shuttle crew at KSC three days prior to their beautiful on-time liftoff on 12 September 1993. Thank you.

JOEL W. POWELL
Alberta, Canada

SPACE '93

Sir, I was particularly honoured and delighted to have the opportunity of participating in the Society's Diamond Jubilee SPACE '93 conference and meet again so many of my friends and colleagues from around the world who are involved with the space programme.

Thank you again for inviting me. I wish you and the Society every success for the future.

Prof GARRY HUNT
London

Sir, I would like to thank the BIS Council and especially Shirley Jones and her staff for organising an excellent SPACE '93 Conference at Hastings. It was a well structured and very well administrated event and a clear statement about the continuing leading role being played by the British Interplanetary Society in these generally dark times in world space activity.

I found the mixture of papers, which covered past achievements and future prospects, to have realistic attitudes towards current political climates and to be very stimulating. The conference as a whole offered exactly the kind of forum that a competent society should provide, where people from diverse fields can interact in conducive surroundings to exchange ideas and experience. It is from such events that new hope, direction and opportunities flow.

I was proud to be able to participate in the Society's 60th Anniversary, being conscious of the influential role it has played in the world, and wish it a creative, active and influential future.

ALAN BOND
Oxon, UK

Sir, May I congratulate you on the superb organisation of the 60th Birthday Celebrations at Hastings. I am certain that all there thoroughly enjoyed themselves and will remember the event for a very long time.

F.W. CLARKE
Somerset, UK

Sir, Having just returned from the SPACE '93 Conference at Hastings I am writing to thank everyone concerned with the organisation of this event. As this was our first conference we were a little unsure what to expect but we were made very welcome by everyone there and enjoyed the whole weekend. The lectures were very informative and it was a privilege to attend the Banquet and Sunday's Satellite Link-Up.

Listening to Buzz Aldrin recounting his landing on the Moon was an unforgettable experience and one that I, like everyone there, will never forget. My only regret was not talking to any of the ESA or NASA people there as I hope one day to work in the space industry - I am a computer consultant.

Once again a big thank-you to everyone involved and I very much look forward to the next such weekend!

RICHARD SIMPSON
Member BIS
Cardiff, UK

Sir, I write to say how much I enjoyed meeting you, your delegates and distinguished guests during the British Interplanetary Society's SPACE '93 Conference.

As I said during my speech, the Conference will undoubtedly remain as one of the true highlights of my Mayoral year.

The high regard in which the Society is held can clearly be demonstrated by the calibre of members and guests alike. It was a very great privilege indeed to meet and shake the hand of the second man on the Moon - something I shall never forget!

I am particularly pleased that the British Interplanetary Society chose Hastings for a third Conference visit, particularly since it was also your 60th Anniversary celebration, and I do hope that our town can welcome you again in the very near future.

The Right Worshipful The Mayor
Councillor Richard Stevens
Hastings, UK

Sir, I would like to express my thanks to the staff of the Society for a first class job organising SPACE 93 in Hastings over the weekend of October 15-17. Where else can one attend presentations of such a high standard on space-related themes? A wide variety of subjects were covered, from the informative (such as Dr W.I. McLaughlin on JPL), to the thought provoking (C.M. Hempsell and A. Bond) amongst the many. Commenting on the 60th Anniversary, Patrick Moore phrased it well when he described the Society as "an ideas association" which is "going to have a very major role to play in the coming century".

Highlights of the event were, of course, the visit of Buzz Aldrin and the live satellite link-up with Arthur Clarke. For those of us writing on space travel topics (and having grown up when the Moon landings were taking place), the chance to interview and listen to what Buzz Aldrin had to say was a real honour; Buzz continues to be a very active producer of ideas on space programmes, both present and future. Arthur Clarke gave us all an insight into his plans, including work on books, TV and a Movie! It was indeed appropriate to see Arthur Clarke by satellite, which worked perfectly. A word of appreciation is in order on the excellent technical job for the satellite link.

I look forward to similar weekends and am confident that the Society will continue as a leading 'ideas association' for the next 60 years.

MICHAEL PHILLIPS FBIS
Kent, UK

Sir, I take this opportunity to tell you how much my wife and I enjoyed the SPACE '93 weekend. It was our third "space" weekend and quite the best; a really splendid way to celebrate the Society's 60th anniversary.

Our hosts, the Mayor and Borough of Hastings as well as our friends BT and Logica (the chocolates were delicious!) did us proud. The satellite link to Arthur C. Clarke was a splendid idea and we were particularly thrilled to meet Buzz Aldrin.

The lecture programme was stimulating and enjoyable, providing a solid foundation for the social and celebratory aspects. We are looking forward to SPACE '95 - or will it be SPACE '94?

We thank you and your staff for all the work that went into organising and running of a tremendous weekend.

TREVOR WAYNE
Kent, UK

Winged Re-Entry

Sir, I was interested to read Mr John A. Silvester's suggestion in ***Spaceflight*** (November 1993, p.389) to use a winged vehicle for Earth planetary entry from the Moon. I would like to refer to my MSc thesis [1] in which the use of winged lifting vehicles for manned interplanetary and lunar missions is thoroughly reviewed.

The main advantages of using high L/D (lift-to-drag) vehicles compared to blunt entry vehicles is that they have very good cross-range capabilities, the planetary entry corridor is larger and therefore the entry is safer and less dependent on guidance systems and they are more manoeuvrable especially in the final stages of flight.

The main disadvantage of winged/lifting bodies apart from poor volumetric efficiencies is that for the lunar superorbital entry velocity (around Mach 36) they incur more radiative heating and more significantly much greater convective heating rates (the largest percentage of the peak heating load). To cope with an entry from the Moon, a body with an L/D of much above 0.5 would probably have to be ablatively shielded like Apollo as opposed to radiatively shielded like the Shuttle as the latter would find it difficult to cope with the stagnation temperatures incurred.

This type of shielding is not really suitable for high L/D types as the aerodynamic characteristics of the vehicle would be difficult to predict after re-entry and a relatively high shield weight is required compared to blunt bodies. Perhaps a discardable blunt entry/sheath ablative heat shield could be used so that once entry had taken place it could be discarded. Future thermal protection systems might be able to employ some form of radiative cooling with an advanced active cooling system similar to that proposed for NASP (National Aero Space Plane).

Whilst winged entry from the Moon might be unfeasible I believe that winged entry to Mars is a much better bet. Tauber *et al* [2,3] have pursued this theme and have proved that for the Mars atmosphere both direct and aerobraking entries are feasible with winged types. They would allow the polar regions of the planet to be explored by way of their excellent cross-range capabilities. The thin Martian atmosphere would mean that the landing of any winged vehicle would have to be a rocket-powered vertical descent.

In addition to the above, winged 'Waverider' planetary entry spacecraft optimised for a specific Mach number have been suggested for use in aero-gravity-assist manoeuvres on planetary 'grand tours' etc. [4].

I would be interested to find out if any work has been done on the feasibility of using a Delta Clipper SSTO (Single-Stage-To-Orbit) type for lunar operations. The vehicle could be refuelled in Earth orbit, fly a landing mission to the Moon and then land vertically following re-entry on the Earth. Delta Clipper being a "lifting vehicle" with a high L/D (above 1) may for the reasons already mentioned be proven to be unsuitable but perhaps a blunter version could be designed specifically for Earth entry from the Moon.

DAVID M. TODD
Middlesex, UK

References

1. David M. Todd, "The Use of Winged/Lifting Body Planetary Entry Vehicles for Manned Interplanetary Missions", MSc Thesis, Cranfield University, September 1992.
2. M.E. Tauber, J.V. Bowles and Lily Young, "The Use of Atmospheric Braking During Mars Missions", NASA Ames Research Center, AIAA 89-1730.
3. M.E. Tauber, J.V. Bowles and Lily Young, "Atmospheric Manoeuvring During Martian Entry", NASA Ames Research Center, AIAA 88-4345.
4. J. Anderson, M. Lewis, A. Kothari and S. Korda, "Hypersonic Waveriders for Planetary Atmospheres", AIAA Paper 90-0358.

Anatoliy Zykov

Sir, No evidence of a Soviet lifting body accident exists, but one report concerning cosmonaut Anatoliy Zykov must be taken into consideration. The Soviet monthly *Sputnik* of January 1970 reported his death in a "glider accident", without giving its date. It said that he was a research engineer at a spacecraft design bureau, and that he had been selected as a cosmonaut on 11 June 1966, but was later disqualified because of his "short height". As the height criterion should have disqualified him before selection, one is lead to suspect that he may have been a cosmonaut. As no details of the "glider" were given, the vehicle may have been of an experimental nature. At the time, the Russians were conducting powered and unpowered flight of the Lapot lifting body, and the glider may have been a derivative of the Lapot.

I would be grateful if anyone can supply any additional information and a photo of Anatoliy Zykov.

HENRY MATTHEWS
Beirut, Lebanon

The following reply has been provided by Mr Rex Hall:

Zykov was rejected as a cosmonaut because he was too tall rather than being too short. Since this piece appeared in *Sputnik* we have a greater understanding of the selection process undertaken for entry to cosmonaut training.

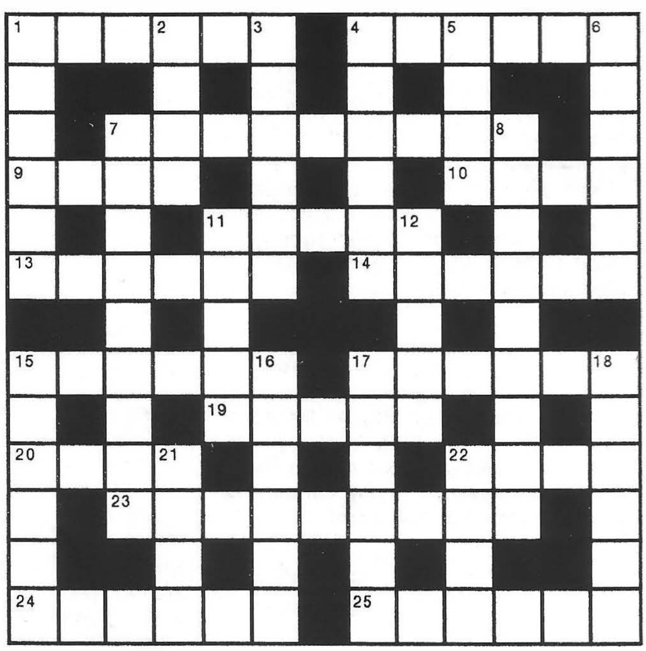
Zykov, of whom no picture has been released, was certainly being included in the

Spaceflight Crossword

No. 4

ACROSS
1. European space launcher
4. Give or take an electron or two
7. About a day, biologically speaking
9. Planet in arms
10. Side of Moon not visible from Earth
11. Astronaut territory
13. Furniture item that sounds like a Search for Extra-Terrestrial Intelligence
14. Composed of soil
15. Processional march
17. Adheres
19. Computer memory unit
20. Rendezvous
22. Ring of light around the Moon
23. Long-established custom
24. Runs away
25. Smart

DOWN
1. ESA pioneering payload for mobile communications
2. Line of rotation
3. No earthly return at this velocity
4. Set electric current flowing in a transformer
5. Not far
6. Work that is conserved by law
7. Diminutive lunar impact feature
8. Pertaining to Neptune
11. Dispatches
12. The —— has landed
15. Highly vesicular material derived from acidic lavas
16. Studies in French
17. Fault-finder
18. Collective term for meteors
21. Single journey
22. Oriental spaceplane



Solution will appear in the January issue.

Solution to Crossword No.3. **ACROSS:** 1. Moon; 3. Spacehab; 9. Three; 10. Olympus; 11. Red; 13. LEO; 14. Guard; 15. Sesame; 17. Snacks; 19. Scour; 20 Ilk; 22. SEI; 24. Evening; 25. Comet; 27. Spyglass; 28. Crew. **DOWN:** 1. Motor; 2. Oar; 4. Proton; 5. Cryogen; 6. Hipparcos; 7. Besides; 8. Seal; 12. Discovery; 15. Systems; 16. Martial; 18. Hinges; 21. Keck; 23. In tow; 26. Mir.

newly formed cosmonaut group of the Energiya (or as then known Korolyov OKB) NPO under the command of Anokhin. This group was founded in 1964. This would explain the anomalies in the original text.

Looking at the careers of cosmonauts, who did go on to join the main cosmonaut team after their selection to the Korolyov team, many did learn to fly gliders and sports planes to help them to further their careers. I would think that Zykov was killed while undertaking this type of activity. All the names of pilots linked to Soviet lifting body programmes are top test pilots of either the Mig design bureau or the Flight Research Centre at Ramanskoye.

Terraforming

Sir, Firstly, let me say that I agree with Mr Ashworth's view (***Spaceflight***, October 1993, p.348) that we should be able to take planets for our needs, as and when we desire, with the proviso that they are lifeless planets. There are, however, a few aspects of his letter which I would like to contest.

Earth may still be a living planet, but, more importantly, due to our interference it is now a dying (or, at least, a seriously ill) planet, as reference to any reliable environmental literature will confirm. Also, to say that Humankind "would be one of the first species to face extinction" because of "our position at the top of the food chain" is incorrect. We are now far less dependent on 'Nature' than we once were - we create our own growing conditions, our own seasons, our own daylight. We manufacture foodstuffs for ourselves and our livestock. Earth is becoming a huge factory, an enormous controlled environment for our own benefit and sustenance. For us, the 'food chain' will soon be little more than a concept, of use only when applied to other lifeforms with whom we share this world.

With regards terraforming, suppose we do "seize the opportunity to invest in space growth now". How long will this process of terraforming and off-world industrialisation take? A realistic minimum figure is four hundred years. In the meantime, what is done to improve the conditions here on Earth? Dr Vincent is right to say we must apply ourselves to the task of repairing the damage we have already done to this planet, and to develop more efficient industrial processes, in other words, reduce the effect we have on the environment. If we don't, when (if?) we reach the day of the Earth Park, we will not have cured the original problem we will have just moved it to another planet.

What we need is for everyone to be suitably educated so we are all made aware of, and are able to minimise, the impact our lifestyles have on the Earth, or Mars, or Planet X.

D.M. FRANCIS
Cheshire, UK

World Government

Sir, With regard to the world government debate (***Spaceflight***, September 1993), I find myself coming down squarely on both sides.

Dr Crawford is probably correct when he says the American Federation was a precondition for Apollo, but Mr Baritsch's point about competition is also well taken. It is surely not in dispute that the perceived threat of the Soviet Union was a major factor in the US decision to go to the Moon in the sixties.

Although Dr Crawford does put forward other plausible motivations that a world government might have for pursuing a strong space programme, I only hope that the Catch-22 does not turn out to be that while only a world government would command the resources necessary for solar system colonisation and interstellar flight, its monopoly position would stifle the political will to actually carry it out.

CHRISTOPHER RILEY
Victoria, Australia

Hanging Models

Sir, It was interesting to see another view on spacecraft modelling in the article 'Space in Miniature' (***Spaceflight***, September 1993) having been involved in the field myself to some degree or other for a good few years.

I was particularly amused to read author Keith McNeill's comment that he had discovered that by hanging models vertically, the model obscures the thread and that "only years later" did he discover that "this method is sometimes used in the film business". Actually it is not "sometimes", it is often, and it only goes to prove that there is no obsolete special effects technique. We may now have computers and motion control and digital effects generators to do wonderful things with effects and miniatures, but there is still the occasion where it is simpler, more reliable and consequently cheaper to hang the model on a piece of string!

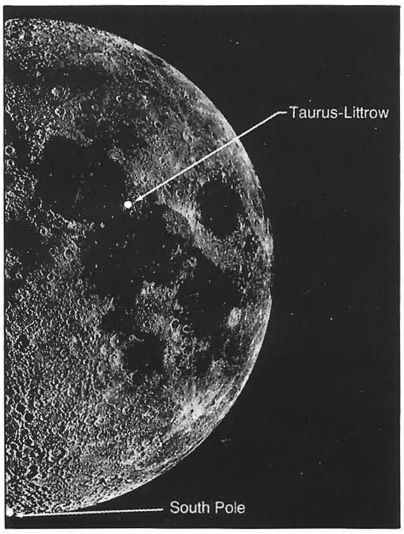
MAT IRVINE
Bucks, UK

'Lunar Landing' Competition

Between 1959 and 1976 there were over 40 successful missions to the Moon of increasing complexity. The first were flyby missions soon to be followed by crash landers, then soft landers and orbiters, and during the final years by manned orbiters, manned landers, unmanned sample returners and lunar rovers.

This month's competition is an opportunity for readers to brush up on a few facts about the lunar landings of these final years.

Prizes: The first correct entry to be opened after the closing date of 6 January 1994 will receive a copy of the book



To a Rocky Moon

by Don E. Wilhelms

This is a recently published book about lunar surface exploration. Details of its contents appear in Book Notices in the August 1993 issue of Spaceflight.

For the next four correct entries to be opened there await Consolation Prizes of the book

Citizens of the Sky

by BIS Fellow Bob Parkinson

To Enter: Match up the following clues with names from the list below:

Near to Surveyor 3 ....
Descartes ....
Flat for safety ....
Mare Crisium ....
First automatic sample return ....
Area of geological diversity ....
Traversed about 10 km ....
Fra Mauro Formation ....
The adjacent picture of the Moon ....
Lander of Lunokhod 2 ....

Title/Name ....
Address ....
....
....

Name List: Apollo 11, 12, 14, 15, 16, 17, Luna 16, Luna 21, Luna 24, Lunokhod 1

Post to: The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, to arrive by first delivery on 6 January 1994.

SATELLITE DIGEST-259

Satellite Digest is our regular listing of world space launches. It is abridged from a more detailed monthly listing, Worldwide Satellite Launches prepared by Phillip S. Clark and published by the Molniya Space Consultancy.

Spacecraft	Int'l Desig.	Launch	Launch Site	Launch Vehicle	Mass kg	Orbital Epoch	Incln. deg	Period min	Perigee km	Apogee km	Notes
UFO 2	1993-056A	Sep 3.47	ER	Atlas-1	2,000 ?	Sep 23.37	5.11	1,436.30	35,138	36,443	[1]
Cosmos 2262	1993-057A	Sep 7.56	Tyuratam	Soyuz	6,500 ?	Sep 8.85	64.89	89.83	207	325	[2]
Discovery	1993-058A	Sep 12.49	ER	Shuttle	92,370	Sep 13.42	28.46	90.33	273	309	[3]
ACTS	1993-058B				1,474	Sep 24.40	0.21	1,437.72	35,708	35,929	[4]
ORFEUS-SPAS	1993-058C				3,207	Sep 15.48	28.46	90.30	273	306	[5]
Cosmos 2263	1993-059A	Sep 16.32	Tyuratam	Zenit-2	9,000 ?	Sep 21.69	71.00	101.96	849	855	[6]
Cosmos 2264	1993-060A	Sep 17.04	Tyuratam	Tsyklon-M	3,000 ?	Sep 18.70	65.03	92.77	403	418	[7]
IRS 1E		Sep 20.22	Sriharikota	PSLV	846	Failed to Reach Orbit					[8]
SPOT 3	1993-061A	Sep 26.07	Kourou	Ariane 40	1,907	Sep 28.25	98.68	101.23	816	818	[9]
Stella	1993-061B				48	Sep 28.74	98.68	100.90	798	805	[10]
KITSAT B	1993-061C				50	Sep 28.95	98.68	100.87	795	805	[11]
POSAT 1	1993-061D				50	Sep 28.81	98.68	100.86	794	806	[12]
HEALTHSAT 2	1993-061E				50	Sep 27.41	98.68	100.85	793	805	[13]
ITAMSAT	1993-061F				12	Sep 28.67	98.68	100.85	796	803	[14]
EYESAT A	1993-061G				12.5	Sep 28.95	98.58	100.84	791	806	[15]
[Cosmos 2265]	1993-062A	Sep 30.71	Tyuratam	Proton-4	2,000 ?	Oct 2.48	1.52	1,441.09	35,849	35,920	[16]

NOTES

1. Also called USA 96 and UHF 2: defense communications satellite initially stationed over 186 °E.
2. Fifth flight in a relatively new series of photoreconnaissance missions: previous similar satellites have disintegrated 6-9 weeks after launch.
3. STS-51 mission, carried six astronauts: F L Culbertson Jr (commander), W F Reddy (pilot), J H Newman (mission specialist, MS-1 and EVA astronaut EV-2) D W Bursch (MS-2) and C E Walz (MS-3, EV-1). Mass quoted above is that projected for landing. Landed at KSC Sep 22.33, first night-time landing at KSC.
4. Communications satellite, planned for deployment over 260 °E. Mass at launch (including items which remained attached to TOS injection stage) was 2,770 kg.
5. US-German astrophysics payload: deployed from shuttle Sep 13.59 and re-captured 1993 Sep 19.41, returned to Earth aboard Discovery.
6. ELINT satellite.
7. Fourth EORSAT launch in 1993, starting a new orbital plane away from the three earlier missions.
8. Refurbished IRS 1A engineering model: remote sensing satellite. Problems at the time of the PSLV second and third stage separation resulted in the third and fourth stages being at the wrong attitude while they burned, preventing sufficient velocity being obtained.
9. CNES remote sensing satellite.
10. CNES passive geodetic satellite.
11. Second Korean satellite, carrying communications equipment, an Earth imaging system and an electron detector.
12. First Portuguese satellite, with an Earth imaging system, cosmic ray detector and communications equipment.
13. Permits medical communications between Africa and Europe/North America. HEALTHSAT 1 was the name given to experiments using UOSAT 3 and UOSAT 5.
14. First Italian amateur radio satellite.
15. Carries experiments concerning location and surveillance of industrial mobile equipment.
16. Different launch announcements identified this as Cosmos 2265 and a Raduga satellite: if it is the latter then it could be either Raduga 30 or Raduga-1 3. To be used for government communications. Currently still drifting to its planned geosynchronous orbit location.

ADDITIONS AND UPDATES

1977-057A Meteor-1 28 (also called Meteor-Priroda 1) decayed from orbit 1993 Aug 28.

1977-082A Molniya-1 38 decayed from orbit 1993 Sep 28.

1984-113B The orbit of Anik-D 2 was stabilised over 19 °E approximately mid-August.

1985-076B During August 19-20 Optus-A 1 was boosted off-station over 160 °E. The satellite was still drifting in mid-September 1993.

1990-091B During Aug 14-17 Galaxy 6 was relocated from 260 °E to 257 °E: no Two- Line orbital data were issued showing the relocation drift orbit.

1991-010A During Sep 9-11 the orbit of Cosmos 2133 was adjusted to a geosynchronous one, with the satellite's longitude stabilised over 79 °E.

1992-088A During Sep 10-14 the orbit of Cosmos 2224 was adjusted to a geosynchronous one, with the satellite's longitude stabilised over 335 °E.

1993-003B Approximately Aug 26 TDRS 6 was manoeuvred off-station over 221-222 °E. At the end of September the satellite was still drifting to its new location.

1993-019A Progress-M 17 is still in orbit. Add the following orbits: Aug 11.77, 51.62°, 92.36 minutes, 388 km, 393 km (just after undocking from Mir) and Aug 12.92, 51.62°, 92.00 minutes, 370 km, 376 km. Spacecraft is expected to remain in orbit for about 1.5 years.

1993-053A The Resurs-F 19 descent module was recovered approximately Sep 10.3.

1993-054A Navstar 22 has been given the alternative designator USA 95: it is currently not known to which satellites the designators USA 93 and USA 94 have been applied. Add the following operational orbit: Sep 24.43, 54.90°, 718.01 minutes, 20,109 km, 20,257 km. Satellite is co-planar with Navstar 18.

1993-055A Meteor-2 21 is co-planar with Meteor-2 19.

1993-055B The mass of Temisat has been reported to be 32 kg.

Launch Report

Cosmonauts Wait for Rocket

The three Russian cosmonauts Viktor Afanasyev, Yuri Usachov and Valeri Polyakov, destined to be launched to Mir on November 16, 1993 are at present not expecting a rocket to become available until early January. The current crew, cosmonauts Vassily Tsibliyev and Aleksandr Serebrov, will then have to stay on board Mir 54 days longer than the planned five months.

The upcoming flight is linked to a new duration record attempt in which physician Valeri Polyakov is to stay on board Mir for fourteen months and two weeks and return by the US shuttle in March 1995. Because of the launch delay the planned sixteen months duration of his flight has been shortened by one and a half months.

On the phone from his Moscow home, Polyakov said: "Of course we are not happy with this situation. There is a complexity of economical and technical problems behind the booster problem. It is not pleasant for us, but neither for the present crew which has to stay longer than the planned five months. But we are confident the booster problem will be solved".

Polyakov and his colleagues began to have their doubts at the beginning of October, when serious problems developed relating to the launch of the resupply ship Progress M-20. Every two months a Progress is launched to Mir to deliver food, water and new experiments; and Progress spacecraft are launched on Soyuz boosters, like the manned Soyuz TM spaceships.

The rocket meant to launch Progress did not become available in time and a desperate search began for a replacement vehicle. At the very last moment it was discovered that the Russian Meteorological Service keeps a few Soyuz boosters in store to launch weather satellites. On October 11, Progress-20 was launched on this booster to link up with Mir on October 13. On October 15, the Russian army newspaper *Red Star* lifted the veil a bit further. The rocket originally meant to launch Progress was ready at the factory - but for the engines. The engine factory in Samara had stopped delivering them because of money problems.

"Can the meteorological service again help out with a flight ready Soyuz booster?" Valeri Baberdin asks in *Red Star*. 'No' was the answer as the Soyuz booster is being produced in two versions. The first version is capable of launching unmanned satellites and - with some modifications - a two-seater Soyuz spacecraft. But to launch three cosmonauts, as the plan is now, a second version is needed. And this one cannot be provided by the meteorological service.

Polyakov says: "How this problem will be solved I do not exactly know. Our launch has now been postponed to January 8, 1994. This means that the present crew will have to stay in Mir for 200 days and not 146 days. The fact that my long duration flight now will be a bit shorter does not bother me too much. We are not looking for records nowadays, but for more medical knowledge".

In theory it would have been possible for the present Mir crew to return on the planned date and leave Mir unmanned for one and a half months. This was done a few years ago, but it cannot be done any more. The condition of the space complex is such that it cannot be left unattended without the risk of losing it altogether.

Peter Smolders

Ariane Launch Just 26 Days After V59

Ariane V60 placed into orbit the first model of a new generation of satellites Intelsat 701. An Ariane 44 LP launcher, fitted with two solid and two liquid-propellant boosters, lifted off on Friday, October 22, 1993 at 03:46:00 local time.

The Intelsat 701 satellite is the first of a new generation of telecommunications satellite developed by Space Systems/ LORAL of Palo Alto (California, USA) for Intelsat. With a lift-off mass of 3,650 kg (8,030 lb) at launch, Intelsat 701 will provide international telephone links, TV programme and video transmission services for the Asia-Pacific region.

Provisional parameters at third stage injection into geostationary transfer orbit were:

Perigee:	200 km (± 3 km) for a target of 199.9 km
Apogee:	35,939 km (± 156 km) for a target of 35,790 km
Inclination:	7° (± 0.6°) for a target of 6.98 degrees.

The next Arianespace launch, Flight 61, is scheduled to take place on the night of November 19, using an Ariane 44L launch vehicle; it will place two satellites into geostationary transfer orbit: Solidaridad for Telecomunicaciones de Mexico, and the European Space Agency's Meteosat 6 on behalf of the Eumetsat Organisation.

DC-X Completes Third Test Flight

On September 30, 1993, The Delta Clipper Experimental (DC-X) completed its third consecutive successful flight at the White Sands Missile Range.

Approximately one second after throttle up from 30 percent to 85 percent thrust, a deviation in thrust built-up which lasted for three to four seconds and resulted in the vehicle staying in the vicinity of the launch stand longer than planned. The on-board flight control system automatically adjusted for this deviation and the four Pratt & Whitney RL-10A5 engines then built up to approximately 95 percent thrust to make up for the time delay.

The vehicle then proceeded to follow its pre-planned flight programme reaching a height of 1,200 feet on time and moving laterally in a straight line for 350 feet. Descending vertically, the vehicle touched down on its landing pad within approximately two feet of the touchdown location of the two prior successful DC-X flights. The entire flight sequence lasted 72.2 seconds.

Forthcoming Shuttle Launches

Mission	Target Date	Orbiter
STS-61	1 December	Endeavour
STS-60	Mid-January	Discovery

Columbia on Two-Week Mission: STS-58

Third time proved lucky as the Space Shuttle Columbia was launched on the STS-58 mission at 10:53:10 am from the Kennedy Space Center's Launch complex 39B on October 18, 1993. Previous attempts on October 14 and 15 had been scrubbed at T-31 seconds with the countdown stopped for the T-9 minute built-in-hold. In both previous attempts a combination of weather and hardware problems combined to halt the launch.

However, October 18 dawned bright and clear and both the KSC weather and weather at transatlantic abort sites cooperated as Columbia began its fifteenth mission. This was the Space Shuttle Program's 58th launch.

STS-58 liftoff from Launch Pad 39B. *NASA*

Countdown Begins

On October 14, mission managers evaluated the Shuttle's condition and the weather projections for the planned launch period and gave a "Go" for loading liquid oxygen and hydrogen propellants into the external tank.

Although the countdown proceeded satisfactorily, the weather situation deteriorated. There was concern that a possible lightning threat might occur due to local conditions. Since the launch window was two hours and thirty minutes long, the opportunity to hold and to await improved weather conditions was taken. The launch count held for about two hours, at which point the weather was improving and so the decision was made to resume the countdown which proceeded without incident up to the T-31 second point. At that instant the launch team was advised by Range Safety that they were "No Go" due to a Range Safety computer failure at the Cape Canaveral Air Force station. Launch safety rules dictated that two of the Range Safety computers be up at launch and only one was then functioning. The orbiter could however, only hold for a maximum of four minutes and fifty-one seconds due to the launch ready configuration of the main propulsion system. After several minutes wait, Range safety indicated that they were "No go for the day" and the launch was scrubbed.

Second Attempt

At the post-scrub analysis launch crews indicated that they could be ready to attempt the launch of STS-58 on the following morning. All systems were able to support this effort and the orbiter APUs, which had been started at the T-5 minute point, had sufficient hydrazine fuel remaining for another launch as well as mission operations.

The countdown was resumed at the T-11 point on the evening of the 14th. The planned launch time was again 10:53 am. Again, weather was a concern as rain and clouds moved into the area. However, a more serious concern arose with the failure of one of Columbia's two S-band radio transponders. The orbiters carry two of these units which allow communications between the Earth and the orbiter during the periods when the Ku-band antenna in the payload bay is stowed with the payload bay doors closed. Mission rules indicated that at least two of these units must be operating for launch and at least one must be operating to continue the mission should a failure occur on-orbit.

The concern of the mission controllers was the possibility of a failure of the second S-band transponder during an ascent stage abort. If that happened, communications with the orbiter would be severely curtailed. This consideration eventually outweighed a proposal to load a good second transponder unit into the orbiter middeck, launch, and replace the failed unit on-orbit. The countdown was scrubbed after having extended the T-9 minute hold to evaluate the situation.

Final Delay

Following the scrub, launch crews began operations to again drain the propellants from the External Tank and place the launch pad and Space Shuttle in a safe condition for work.

Due to the requirement to remove and replace the rodents inside the SLS-2 module, the next launch attempt was planned for the following Monday, October 18. On Saturday the 16th, the S-band transponder was removed and replaced, and the replacement unit checked out with the orbiter systems. Preparations began for the lowering of a technician down inside the Spacelab module from the orbiter middeck area. The removal and replacement of time-critical Spacelab stowage, including 48 rodents, was completed by the morning of Sunday October 17. The countdown was restarted at the T-11 hour point at 8:33 pm on that evening.

To conform to their on-orbital schedules, the flight crew were awakened at staggered times from about 5:33 am to approximately 5:58 am. Breakfast began at about 6:13 for MS-4 and PS-1 and 6:28 for the rest of the crew. MS-4 and PS-1 began putting on their flight equipment at 6:33 am. A weather briefing was at 6:58 am and the remainder of the crew began donning their flight equipment following the weather briefing. The STS-58 crew left their KSC quarters at the Operations and Checkout building at about 7:38 am and entered Columbia at approximately 8:08 am.

The countdown proceeded without major incident until shortly before the T-5 minute mark when Range Safety indicated an unauthorised naval aircraft was in the area. The count was held briefly at the T-5 minute point as the range made sure the aircraft was clear and then was able to be resumed 10 seconds later after confirmation of the aircraft's position had been made.

The final five minutes went smoothly. The APUs (Auxiliary Propulsion Units) were started, the orbiter's aerosurface profile test came shortly after T-4 minutes, Columbia was transferred to internal power at T-3:30 as the main engines ran their gimbal profile test. The External Tank oxygen tank was pressurised and then the hydrogen tank. SRB joint heaters were deactivated one minute before liftoff. At T-31 seconds the Launch Processing System gave a go for the start of the final automatic sequence and at 10:53:10 am on the morning of Monday October 18, 1993 STS-58 began its mission by lifting off from the Kennedy Space Center's launch complex 39B.

Roelof L. Schuiling

(Columbia touched down at 15:06 GMT on November 1 at Edwards Air Force Base. A full STS-58 Shuttle Mission Report is due to appear in a forthcoming issue.)

Second Kazakh Cosmonaut to Mir

According to the newspaper *Baikonur*, published in the city of Leninsk which serves the Russian cosmodrome, the decision has been taken to include a representative of Kazakhstan in a crew to be sent to Mir in May 1994. The crew will consist of the Russians Yuri Malenchenko, Gennady Strekalov and Talgat Musabayev from the Republic of Kazakhstan, who served as back-up for cosmonaut Tokhtar Aubakirov at the time of his flight to Mir in 1991.

For the Russians it is politically very important to again fly a Kazakh cosmonaut and strengthen ties with the Kazakhstan Space Agency. The Russian launch site Baikonur lies on the territory of the now independent republic of Kazakhstan. Discussions about the financial aspects of this relationship are still going on. ***Peter Smolders***

SOCIETY ANNOUNCEMENTS

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.

It may occasionally happen that, for reasons outside its control, the Society has to change the date or topic of a meeting. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always recheck the scheduled meetings in the latest issue.

1 December 1993 — 7 - 8.30 pm

WHOOSH!
Space Propulsion Systems Past, Present and Future

Chris Welch, Kingston University

The underlying aim of any space propulsion system is to generate a force which can be used to change the trajectory of the spacecraft. This force can be generated in many ways. This talk looks at the different forms of space propulsion system that have been suggested in the past, those that are in current use, and those that have been proposed for the future.

LIBRARY

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. The Library will also be open between 10.00 am and 1.30 pm on Saturday, 18 December.

Membership cards must be produced.

Society's Postal Ballot
Report of Scrutineers

WE, the undersigned, having been appointed by the Council as Scrutineers for the Society's postal ballot ordered by the Council on the 27th August 1993 in accordance with Article 29 of the Society's Constitution, do herby certify that we have examined the ballot papers and do report as follows:

1. The total number of voting papers was 629.
2. The total number of voting papers rejected was 13, six of which were deemed to be spoiled papers, and seven of which were received out of time.
3. The total number of votes cast in favour of the motion was 157.
4. The total number of votes cast against the motion was 459.
5. We therefore find the motion to have been defeated.

Cyril Horsford, FBIS
Barrister
E.M. Waine, FBIS

11th October 1993

'Space Dates' Competition Winners

Lucky readers to whom books will shortly be dispatched are:

First Prize:

M. Williamson	UK

Consolation Prizes:

F. Dohlen	Norway
C.E. Noad	UK
M. Schuetz	USA
E. Tandberg	Norway

The correct answers are: 1. 1865; 2. 1901; 3. 1906; 4. 1927; 5. 1914*; 6. 1942; 7. 1950; 8. 1956; 9. 1963; 10. 1967; 11. 1971; 12. 1975; 13. 1981; 14. 1984; 15. 1988*.

* Answers within one year of these dates were also accepted due to misprints in the original announcement.

BIS APPEAL

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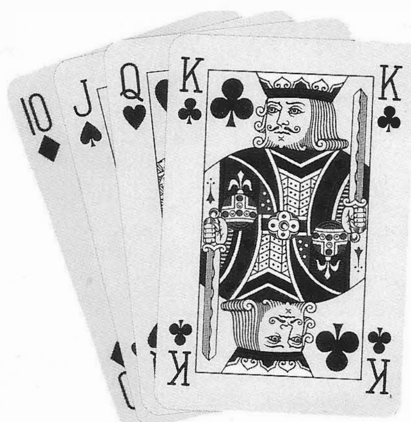

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JBIS

The December 1993 issue of the Journal of the British Interplanetary Society is now available and contains the following papers:

General Issue

A Review of Recent American Military Space Operations

•

Psychological Challenges of Manned Spaceflight

•

Contamination and Cleanliness Control of The ROSAT Wide Field Camera

•

Quasi Stationary Orbits

Copies of JBIS, priced at £15.00 (US$27.00) to non-members, £5.00 (US$9.00) to members, post included, can be obtained from the address below. Back issues are also available.

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